Delaware Climate Action Plan Supporting Technical Greenhouse Gas Mitigation Analysis Report

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Submitted to:
DNREC Division of Climate, Coastal and Energy

Submitted by:
ICF

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Glossary

AEO	Annual Energy Outlook
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BAU	Business as usual
CAP	Climate action plan
CARB	California Air Resources Board
CBECS	Commercial Buildings Energy Consumption Survey
CNG	Compressed natural gas
DAQ	Division of Air Quality
DCCE	Division of Climate, Coastal and Energy
DG	Distributed generation
DNREC	Department of Natural Resources and Environmental Control
EE	Energy efficiency
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EV	Electric vehicle
GHG	Greenhouse gas
GWP	Global warming potential
HDV	Heavy duty vehicle
HFC	Hydrofluorocarbons
IECC	International Energy Conservation Code
IPCC	Intergovernmental Panel on Climate Change
LCFS	Low Carbon Fuel Standard
LDV	Light duty vehicle
LDAR	Leak detection and repair
LIHEAP	Low Income Home Energy Assistance Program
LULUCF	Land use, land use change, and forestry sector
NPV	Net present value
NREL	National Renewable Energy Laboratory
PHEV	Plug in hybrid electric vehicles
PTC	Production Tax Credit

PV	Photovoltaic
REC	Renewable energy credits
RGGI	Regional Greenhouse Gas Initiative
RNG	Renewable natural gas
RPS	Renewable Portfolio Standard
RRHACE	Replace or Repair Heaters and Conserve Energy
SEDS	State Energy Data System
SEU	Sustainable Energy Utility
SIT	State Inventory Tool
TZEV	Transitional zero electric vehicle
USCA	United States Climate Alliance
VMT	Vehicle miles traveled
WAP	Weatherization Assistance Program
ZEV	Zero emission vehicles

Executive Summary

In response to the growing effects of climate change, and to further Delaware's efforts to reduce greenhouse gas (GHG) emissions, Delaware's Department of Natural Resources and Environmental Control (DNREC) is developing a statewide climate action plan (CAP). DNREC engaged ICF Incorporated, LLC (ICF) to support the planning process through technical analyses to characterize and model GHG emission sources and potential reductions. This report focuses on the key technical components of the climate action planning process, which include:

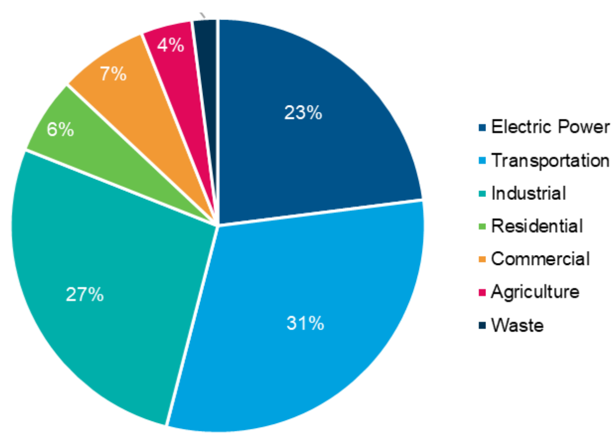
- **Component 1.** Understand the current landscape within Delaware in terms of current levels of GHG emissions and existing mitigation efforts ("Delaware's GHG Inventory and Existing Mitigation Efforts").
- **Component 2.** Understand a "business as usual" (BAU) trajectory, or the forecast of GHG emissions if no additional action were taken to reduce emissions in Delaware beyond what is happening today ("BAU Projections").
- **Component 3.** Identify and analyze a set of feasible actions that can be taken in Delaware to reduce GHG emissions in the short-, mid-, and long-term future ("Mitigation Actions Selection and Analysis").

Component 1. Delaware's GHG Inventory and Existing Mitigation Efforts

The first component of the climate action planning process is to understand the current GHG emissions and existing efforts to reduce those emissions. To understand current GHG emissions DNREC's Division of Air Quality (DAQ) conducts an annual GHG emissions inventory. The 2016 GHG Inventory, released in July 2019, includes GHG emissions from 1990 to 2016 for the following sectors: electric power, transportation, industrial, residential, commercial, agriculture, and waste. In the 2016 GHG Inventory, transportation was the largest source of emissions followed by the industrial and electric power sectors, respectively.

Figure 1 shows the results of Delaware's 2016 GHG Inventory by these sectors. The Delaware GHG inventory only accounts for emissions generated within the state. More specifically, GHG emissions sourced from the electric power sector are only those associated with electricity generated by in-state power generation facilities. Because not all electricity used in Delaware is generated in-state, the inventory also separately reports emissions as a result of electricity consumed in Delaware; however, these emissions are not accounted towards the state total.

Figure 1. Breakout of Emissions in the 2016 Delaware GHG Inventory



A range of programs and policies, such as energy efficiency incentives and a requirement for renewable energy procurement and generation across the state ("a Renewable Portfolio

Standard") are being used right now to reduce GHG emissions in the state and provide various environmental, health, and economic benefits to Delawareans.

Component 2. BAU Projections

The second key component of the climate action planning process is to develop a "Business as Usual" (BAU) scenario for the state's current and projected GHG emissions. The BAU represents a GHG emissions scenario through 2050 under the assumption that no additional actions will be taken, nor new policies put in place in the future to reduce emissions, i.e., business will proceed as usual. The BAU serves as reference for both understanding whether Delaware will meet GHG emission goals and for estimating the GHG emission reductions that could be achieved if GHG mitigation measures are taken.

ICF conducted an analysis to develop a BAU for the state (Figure 2). The BAU provides data for the years 2005 - 2050; reported values from the year 2018 and beyond are projections. This analysis takes into consideration existing policies and programs at the state and federal level and makes assumptions about future economic conditions. The BAU analysis relies on a modified GHG accounting approach as compared to the GHG inventory presented in Figure 1 above. This modified approach focuses on the amount of electricity *consumed* in Delaware and estimates GHG emissions from electricity generated both in-state and out of state to meet Delaware's demand.

BAU Sector Descriptions

Below are brief descriptions of the types of emissions attributed to each sector. Note that the electric power sector accounts for all emissions related to electricity used within Delaware, a different approach than that used for the state GHG inventory.

Agriculture: Includes all emissions from agricultural activities including fuel use, fertilizers, and livestock emissions.

Commercial Buildings: Includes emissions from commercial building activities, such as office building and on-site fuel combustion for heating.

Electric Power: Includes all emissions associated with electricity generated for consumption (both from in-state and out-of-state generation sources).

Industry: Includes emissions associated with industry activities, such as physical and chemical material processing and manufacturing.

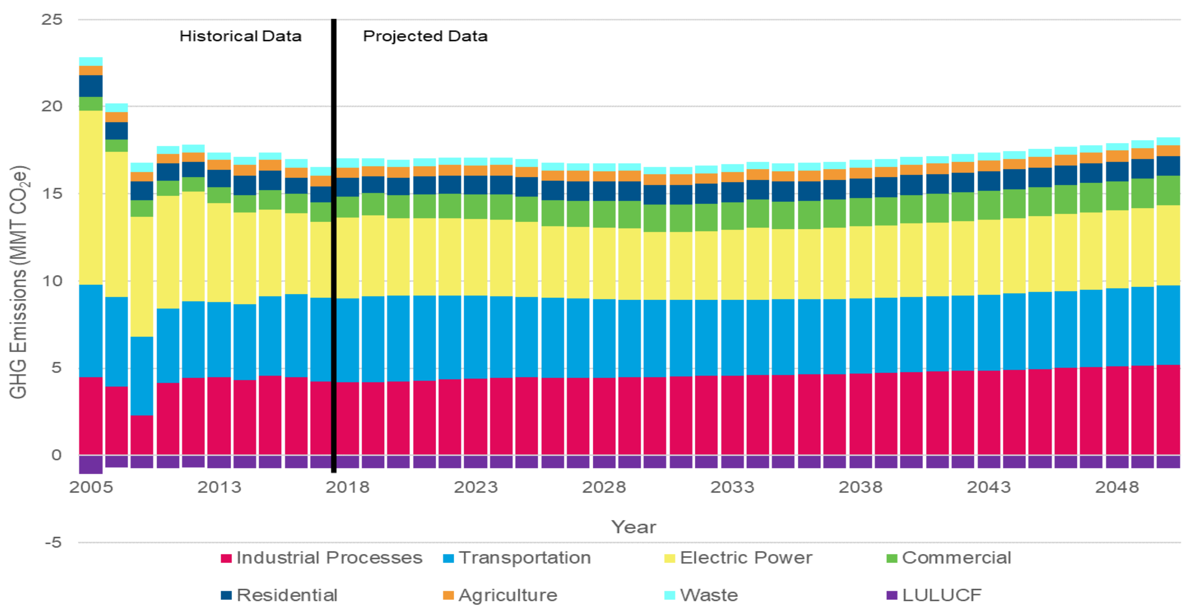
Land Use/Forestry (LULUCF): Includes emissions from land use and forestry activities, where carbon is either captured (sequestered) or released depending on land use.

Residential Buildings: Includes emissions from home residences, such as on-site fuel combustion for heating.

Transportation: Includes emissions generated from the transportation of goods, people, and services, particularly burning fuel for combustion engines.

Waste: Incudes emissions from waste disposal activities, including methane released from landfills.

Figure 2. Net BAU Emissions (MMTCO$_2$e) by Sector Through 2050



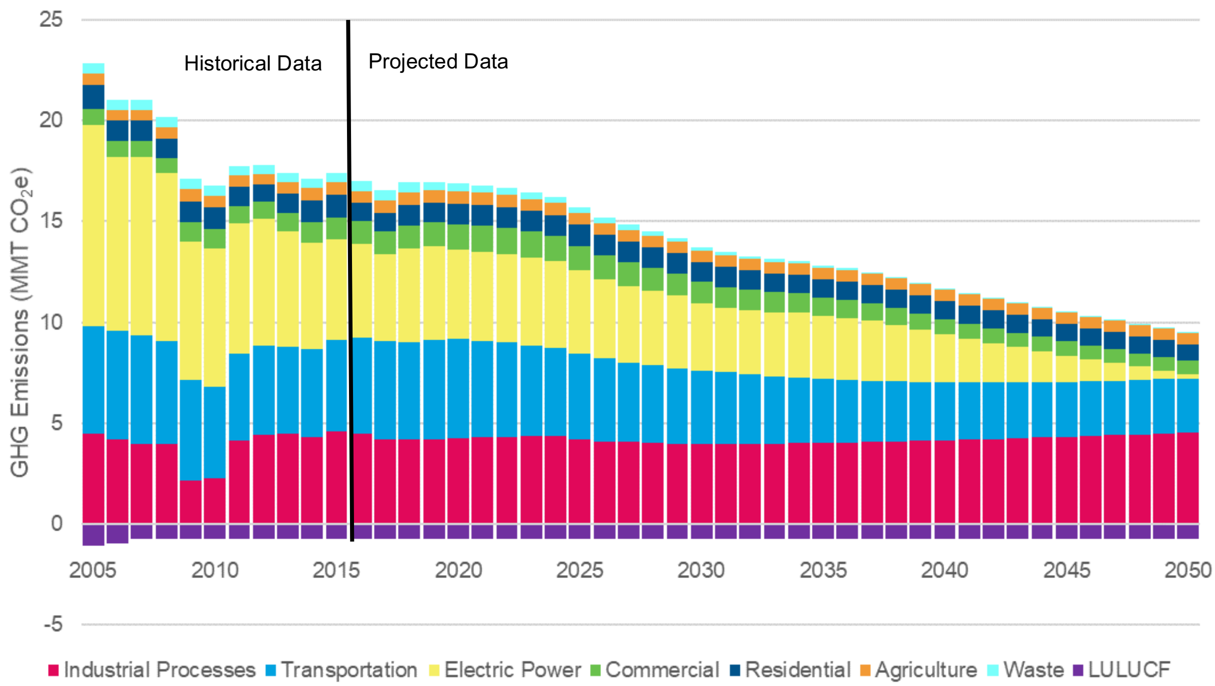
The BAU analysis indicates Delaware's GHG emissions will be reduced by 25.4% in 2025 and by 19.6% in 2050 from 2005 levels (Figure 2). The projection indicates that Delaware is close to meeting its goal of 26-28% emissions reductions by 2025 from 2005 levels. The trend of decreasing state GHG emissions through 2025 results from current state policies and past and anticipated regional energy trends, primarily due to a shift from coal to natural gas-powered electricity. The analysis also indicates that without additional action, GHG emissions will decrease until 2032, when they will begin to rise again as a result of projected population and economic growth.

The BAU analysis indicates that Delaware is at a critical point in its progress towards GHG mitigation. The state has the opportunity to meet or exceed its climate goals for 2025 while also evaluating and putting into place mid and long-term strategies to ensure further emissions reductions after 2025. The Intergovernmental Panel on Climate Change (IPCC) indicates that worldwide CO_2 emissions must reach net zero by 2050 to stop warming beyond 1.5°C and to avoid the worst consequences of climate change (IPCC 2018). Given this, DNREC and ICF modeled emissions through 2050.

Component 3. Mitigation Actions Selection and Analysis

The third component of the climate action planning process is to select and analyze mitigation actions for GHG reduction effectiveness and, for some of the selected actions, their costs and economic benefits. Using feedback and input from technical experts and the public, ICF and DNREC developed a list of 20 mitigation actions for which to model emission reduction potential. These actions are varied and include actions such as energy efficiency, clean transportation, renewable energy, and waste reduction. A smaller subset of actions was selected for economic analysis. These actions, along with many others, may be considered for incorporation into the State's CAP.

Figure 3. Net GHG Mitigation Action Analysis Results for 2005-2050

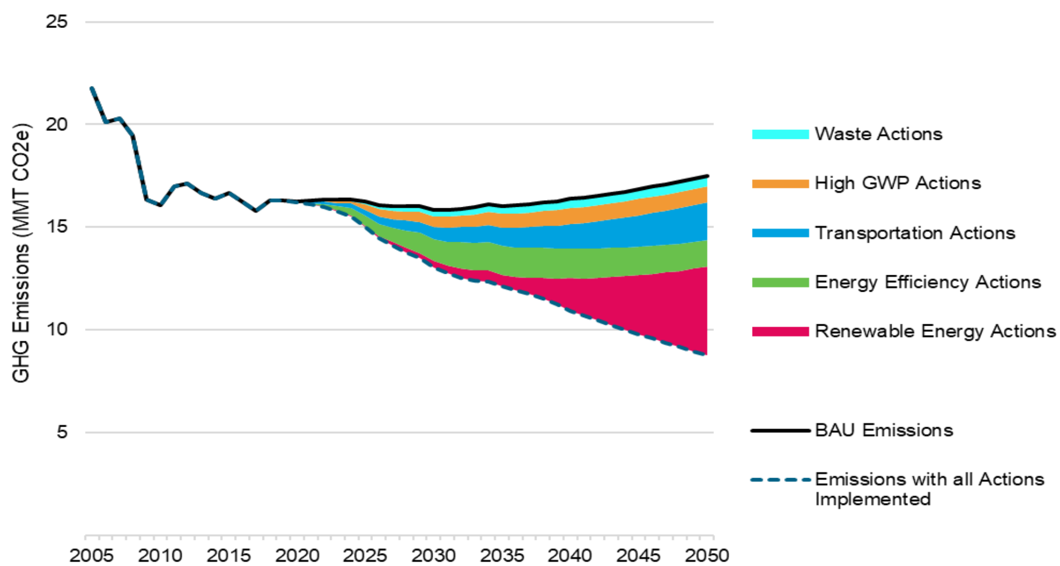


The GHG mitigation analysis shows that if all modeled actions were fully implemented, Delaware's net GHG emissions will decline from 2005 levels by 31.1% in 2025 and 59.7% in 2050 in the GHG mitigation scenario (Figure 4). This represents a decrease in emissions by an additional 5.7% and 40.1% from 2005 levels in 2025 and 2050, respectively, compared to the BAU scenario.

It should be noted that each mitigation measure was assumed to have a different implementation start date, resulting in the 20 actions being phased in over time throughout the analysis. ICF assumptions regarding market factors and available technology guided estimations for when each action is implemented.

The GHG mitigation analysis can also be examined in terms of types of action (Figure 4). Mitigation actions were grouped into the following "type" categories: Waste (waste sector emissions), High Global Warming Potential (GWP) (commercial and industrial sector emissions), Transportation (transportation sector emissions), Energy Efficiency (residential and other commercial sector emissions), and Renewable Energy (centralized and distributed generation-related emissions for all electricity-using sectors) (see Figure 4).

Figure 4. Net GHG Emissions Mitigation ($MMTCO_2e$) by Mitigation Action Category



Key takeaways from the mitigation analysis include:

- Decarbonizing the electricity grid has the greatest potential for reducing GHG emissions in the medium and long terms and drives emission reductions for many actions. Decarbonizing other energy sources may also play a larger, longer-term role in Delaware.
- Electrification of transportation and buildings can also lead to notable GHG reductions over time, but are dependent on decarbonizing the grid for full effectiveness.
- Energy efficiency is an important strategy that can be implemented in the short-term and is a relatively lower cost strategy for reducing GHGs.

Mitigation actions have varying levels of GHG reduction effectiveness over time and when integrated. For example, energy efficiency, which is implemented earlier and consistently through 2050 in the modeling is effective, but gets more effective in reducing emissions when paired with renewable energy actions during later periods of time through 2050.

ICF modeled 7 of the 20 actions for costs and savings, based on readily available data and information. The results of the cost and savings analysis for the subset of actions indicate varying cost-effectiveness of actions. Energy efficiency actions result in net savings due to relatively lower capital investment compared to other actions and higher energy savings, whereas actions with larger investments (e.g., those with larger infrastructure needs and changes) tend to have higher costs. The cost estimates presented in this report are high-level and indicative. In-depth cost analyses may be beneficial for various actions separate from this analysis as the State considers moving into either policy or program design or implementation of a CAP.

Key Terms in Emission Reductions

Decarbonization: Long-term strategies to reduce CO_2 emissions by phasing out the use of carbon-emitting processes and technologies, primarily by eliminating the combustion of fossil fuels as an energy source, with the end goal of a carbon-free global economy.

Electrification: The process of replacing technologies that use fossil fuels as an energy source with technologies that use electricity instead, with the expectation that the electricity is generated using a cleaner energy mix. For example, by electrifying cars, gasoline and diesel-powered engines are replaced with batteries powered by electricity from the grid, which likely includes a mix of renewable and/or clean energy sources that result in less GHG emissions than burning gasoline.

Energy Efficiency: The replacement of older or less energy efficient appliances, vehicles, building materials, and other technologies with newer, more efficient designs that require less energy. Efficiency improvements can provide both emission and cost savings in the short-term.

Together, decarbonization, electrification, and energy efficiency interact closely as major drivers of emission reductions. Efficiency improvements reduce energy demand, electrification drives efficiency and creates opportunity to shift to potentially cleaner energy sources via renewable electricity, and decarbonization reduces emissions from energy.

Summary and Next Steps

Implementing the mitigation actions modeled in the analysis would enable Delaware to exceed its goal of 26-28% emissions reductions by 2025. Moreover, the GHG mitigation analysis can be used to support the development of long-term climate goals and specific mitigation actions to include in the Delaware CAP.

With the BAU Projections and Mitigation Actions Selection and Analysis now developed, DNREC can consider how to use these resources for planning and implementation. The BAU Projections provide the foundation of baseline emissions and can be readily updated to reflect for changes in emission sources and additional data. The Mitigation Actions Selection and Analysis maps out a pathway for reducing emissions and can be adjusted for assumptions, modeling approaches, and mitigation actions. Moving towards implementation will require DNREC, other state agencies, and key stakeholders to collaborate in considering mitigation action timelines; mechanisms for implementation, including tracking emissions and progress on actions; policy or program design elements; costs to the state or its consumers; health and economic benefits; and equity in terms of benefits and impacts. Such considerations will ensure that DNREC and Delaware can successfully achieve long-term emissions reductions, while providing valuable benefits to stakeholders.

Introduction

In response to the growing effects of climate change, and to further Delaware's efforts to reduce greenhouse gas (GHG) emissions, Delaware's Department of Natural Resources and Environmental Control (DNREC) is developing a statewide climate action plan (CAP). DNREC engaged ICF Incorporated, LLC (ICF) to support the planning process through technical analyses to characterize and model GHG emission sources and potential reductions. This report focuses on the key technical components of the climate action planning process, which include:

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Contents, Uses, and Limitations of this Report

This report presents the methodology, results, and key takeaways of the technical analysis for each of the above identified components. The information in this report is intended to be considered by DNREC and its stakeholders as part of developing Delaware's CAP. More specifically, the contents of this report are designed to:

- Quantify and explain the emissions reduction potential of specific actions in the short, medium, and long term.
- Identify indicative costs and savings of specific emission reduction actions.
- Educate DNREC, stakeholders, and the public about the benefits and costs of actions.
- Provide information to help inform a GHG reduction strategy that meets the state's near-term goal and help inform longer-term goals for the State of Delaware.
- Present information about potential approaches to implement mitigation actions.

The contents of this report reflect a rigorous process used to gather feedback and identify a set of mitigation actions which were modeled by ICF. Due to the realities of time and resources constraints, as well as data availability, ICF did not analyze all possible options for GHG emission reductions within the state of Delaware. The information in this report represents a subset of potential actions that were modeled by the project team and should not be interpreted as the only set of actions that can be taken to reduce GHG emissions; nor should the summary information presented be interpreted as the full potential costs and benefits of GHG reduction actions for the state. Additionally, note that the methodology and resulting modeling and analysis do not consider the impacts of the COVID-19 pandemic.

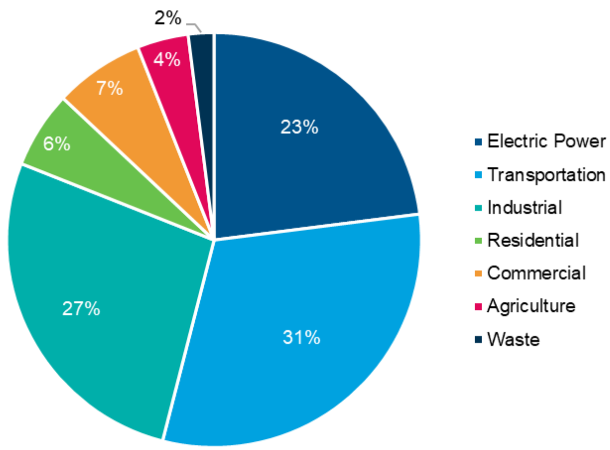
Component 1. Delaware's GHG Inventory and Existing Mitigation Efforts

The first component of the climate action planning process is to understand the current GHG emissions and existing efforts to reduce those emissions.

Delaware's GHG Inventory

DNREC's Division of Air Quality (DAQ) conducts an annual GHG inventory of in-state GHG emissions. The 2016 GHG Inventory, released in July 2019, includes GHG emission estimates from 1990 to 2016 (DNREC, 2019). Delaware's 2016 GHG Inventory was developed using the U.S. Environmental Protection Agency's (EPA) State Inventory Tool (SIT). The SIT breaks emissions into the following sectors: electric power, transportation, industrial, residential, commercial, agriculture, and waste. In the 2016 GHG Inventory, transportation was the largest source of emissions followed by the industrial and electric power sectors, respectively. Figure 5 shows the results of Delaware's 2016 GHG Inventory by sector.

Figure 5. Breakout of Emissions in the 2016 Delaware GHG Inventory



The Delaware GHG inventory only accounts for emissions generated within the state. More specifically, GHG emissions sourced from the electric power sector are only those associated with electricity generated by in-state power generation facilities. Since not all electricity used in Delaware is generated in-state, the inventory also separately reports emissions as a result of electricity consumed in Delaware; however, these emissions are not accounted towards the state total.

Delaware's Existing Mitigation Efforts

As a member state of the U.S. Climate Alliance (USCA), Delaware has committed to a 2025 emissions reductions goal of 26-28% below 2005 levels. Delaware does not currently have any longer-term climate goal commitments beyond 2025.

Delaware has been engaged in efforts to reduce emissions, improve air quality, and reduce cost of electricity for decades. These efforts span a range of agencies, programs, and sectors including energy efficiency, renewable energy, clean transportation, industrial pollutants, and land use. Examples of these types of efforts are described below.

Through strong legislative and regulatory efforts, stakeholder engagement and collaboration, and participation in programs like the Regional Greenhouse Gas Initiative (RGGI), Delaware has made successful strides toward reducing GHG emissions. In 2013, the creation of the Cabinet Committee on Climate and Resiliency created under *Executive Order 41: Preparing Delaware for Emerging Climate Impacts and Seizing Economic Opportunities from Reducing*

Emissions provided a path forward for ambitious climate mitigation and adaptation efforts (DNREC 2020b). Since then, Delaware, and particularly DNREC's Division of Climate, Coastal and Energy (DCCE), and related divisions, have demonstrated a commitment to addressing the impacts and causes of climate change through plans, actions, and programs.

Delaware has implemented several programs that target GHG emissions reductions in the transportation sector including the Delaware Clean Cities Coalition and Clean Transportation Incentive Program. The Delaware Clean Cities Coalition helps residents, businesses, and fleet operators work together to reduce petroleum use in the transportation sector. By developing strategic partnerships and providing tools and resources, the Coalition helps programs transition to alternative fuels and meet goals for petroleum reduction (DNREC 2020c). Delaware's Clean Transportation Incentive Program offers rebates to individuals and businesses statewide toward the purchase or lease of electric and alternative fuel vehicles and charging stations (State of Delaware 2020). Delaware is also engaged in the policy design process of the Transportation & Climate Initiative, a regional collaboration of 12 Northeast and Mid-Atlantic states and the District of Columbia that seeks to improve transportation, develop the clean energy economy, and reduce carbon emissions from the transportation sector.

Delaware has also taken initiative on the clean and renewable energy front. Delaware's Green Energy Program targets transitions to clean energy in the residential and commercial sectors by offering grants to reduce the cost of purchasing clean energy equipment for residences and businesses. Delaware's Renewable Portfolio Standard (RPS) requires utilities to source an increasing percentage of electricity from renewable sources, with a mandate of 25% renewably sourced electricity by 2025, creating a market for the sale of renewable energy credits (RECs) (DNREC 2020d).

Delaware is also working to accelerate the transition away from high global warming potential (GWP) hydrofluorocarbons (HFCs)—chemicals frequently used as refrigerants and extinguishing agents—through a voluntary incentive program (Cool Switch Low Impact Refrigerant Program) and a proposed new regulation (Proposed Regulation 1151: Prohibitions on Use of Certain Hydrofluorocarbons in Specific End-Uses). A regulation with prohibition schedules for certain end-use-specific HFCs will drive industry towards using chemicals with lower GWP, and when paired with the voluntary incentive program that alleviates costs of switching to low-GWP technology a more efficient transition in the state can be achieved.

Other key programs and initiatives in the state of Delaware focused on buildings emissions include the Delaware Energy Efficiency Advisory Council, the Delaware Energy Efficiency Investment Fund, Energize Delaware, and model building energy codes.

Component 2. Business as Usual Projections

The second technical component of the climate action planning process is to develop a BAU scenario for the state's current and projected GHG emissions. The BAU represents a GHG emissions scenario under the assumption that no additional actions will be taken, nor will new policies or programs be implemented in the future to reduce emissions, i.e., business will proceed as usual. The BAU serves as both a reference for estimating the necessary emission reductions Delaware must achieve to accomplish its GHG reduction goal, as well as a baseline for comparing the incremental GHG benefits of additional mitigation actions.

BAU Methodology

The BAU analysis includes GHG emisison projections for all sectors of Delaware's economy for the seven gases recognized by the Kyoto Protocol as prominent GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Emissions projections are made through 2050. The analysis estimates emissions resulting from both in state and out of state electricity generation (see adjacent text box). The analysis is built upon publicly available and credible sources that provide activity data and emission factors, mainly from:

- Delaware's 2016 GHG Inventory, prepared using the U.S. EPA SIT;
- Activity data, emission factors, and methods from the U.S. EPA's SIT and Projection Tool;
- Historical activity data from the Energy Information Administration's (EIA) State Energy Data System (SEDS);
- Forecasted activity data from the EIA's Annual Energy Outlook (AEO); and
- Policies and assumptions from existing federal and DNREC data.

In developing the BAU projections, ICF and DNREC considered various scenarios before selecting a final BAU trend to be used to analyze GHG reductions as a result of mitigation actions. These scenarios included variations of supporting data and assumptions based on the AEO Reference Case; the AEO Reference Case with the state RPS frozen in 2019; and relying on alternative AEO scenarios available, including the High Economic Growth, Low Economic Growth, High Oil Price, and Low Oil Price. Ultimately, ICF and DNREC decided to choose the AEO Reference Case as the scenario for the BAU.

Accounting for Electricity Sector Emissions

The 2016 Delaware GHG Inventory uses a generation-based approach to estimate electricity emissions, which only considers emissions from in-state electricity generation (about two-thirds of all Delaware electricity consumption). In contrast, the BAU and subsequent mitigation analysis make use of an approach based on total electricity consumption to estimate emissions, which allows the use of an emission rate for electricity that reflects both in-state and out-of-state electricity generated to meet Delaware's electricity demand. To implement this approach, the ICF emissions model is built on the assumption that all electricity generated within Delaware is used in Delaware and that remaining electricity demand is met by imported power or distributed generations. This assumption results in a weighted average emission factor for each year based on the amount and type of in-state fossil fuel generated electricity, grid renewable electricity in line with the state RPS, and other imported electricity from the region, which is then used along with electricity consumed to estimate GHG emissions. All emissions presented in this report, with the exception of Delaware's 2016 GHG Inventory, rely on this GHG accounting approach.

Note that all figures, table, and in-text numbers in this report are for the AEO Reference Case scenario with the Delaware RPS implemented (i.e., not frozen) through 2025. Also note that the analysis is based on the federal fuel efficiency standards prior to the 2020 rule rolling these standards back. There are several regulatory actions that are not captured in the BAU, including updated energy building code and proposed HFC regulations. Also note that this methodology and the resulting modeling and analysis do not consider the impacts of the COVID-19 pandemic.

The IPCC indicates that worldwide CO_2 emissions must reach net zero by 2050 to stop warming beyond 1.5°C and to avoid the worst consequences of climate change (IPCC 2018). As a result of this framing, many state, local government, and organizational CAPs use 2050 as a long-term target for modeling emissions. DNREC decided to model emissions through 2050 to be consistent with these CAP approaches and the IPCC.

BAU Results

Figure 6 presents Delaware's BAU emissions by sector. All emissions associated with electric power consumption are encompassed in the electric power sector, and account for both in state and out of state generated electricity. The remaining emissions for industrial processes, commercial, residential, and transportation sectors account for direct fuel consumption, refrigerant, and process emissions. Additionally, emissions and carbon sequestration within the land use, land use change, and forestry sector (LULUCF) are presented, resulting in total net emissions for the state. The amount of carbon sequestered and stored in this sector is greater than emissions and are thus negative. Note that sequestration refers to natural sequestration in this case, not geologic sequestration. In Figure 7, GHG emissions are presented by type of GHG.

BAU Sector Descriptions

Below are brief descriptions of the types of emissions attributed to each sector. Note that the electric power sector accounts for all emissions related to electricity used within Delaware.

Agriculture: Includes all emissions from agricultural activities including fuel use, fertilizers, and livestock emissions.

Commercial Buildings: Includes emissions from commercial building activities, such as office building and on-site fuel combustion for heating.

Electric Power: Includes all emissions associated with electricity generated for consumption (both from in-state and out-of-state generation sources).

Industry: Includes emissions associated with industry activities, such as physical and chemical material processing and manufacturing.

Land Use/Forestry (LULUCF): Includes emissions from land use and forestry activities, where carbon is either captured (sequestered) or released depending on land use.

Residential Buildings: Includes emissions from home residences, such as on-site fuel combustion for heating.

Transportation: Includes emissions generated from the transportation of goods, people, and services, particularly burning fuel for combustion engines.

Waste: Incudes emissions from waste disposal activities, including methane released from landfills.

Figure 6. Net BAU Emissions (MMTCO$_2$e) by Sector Through 2050

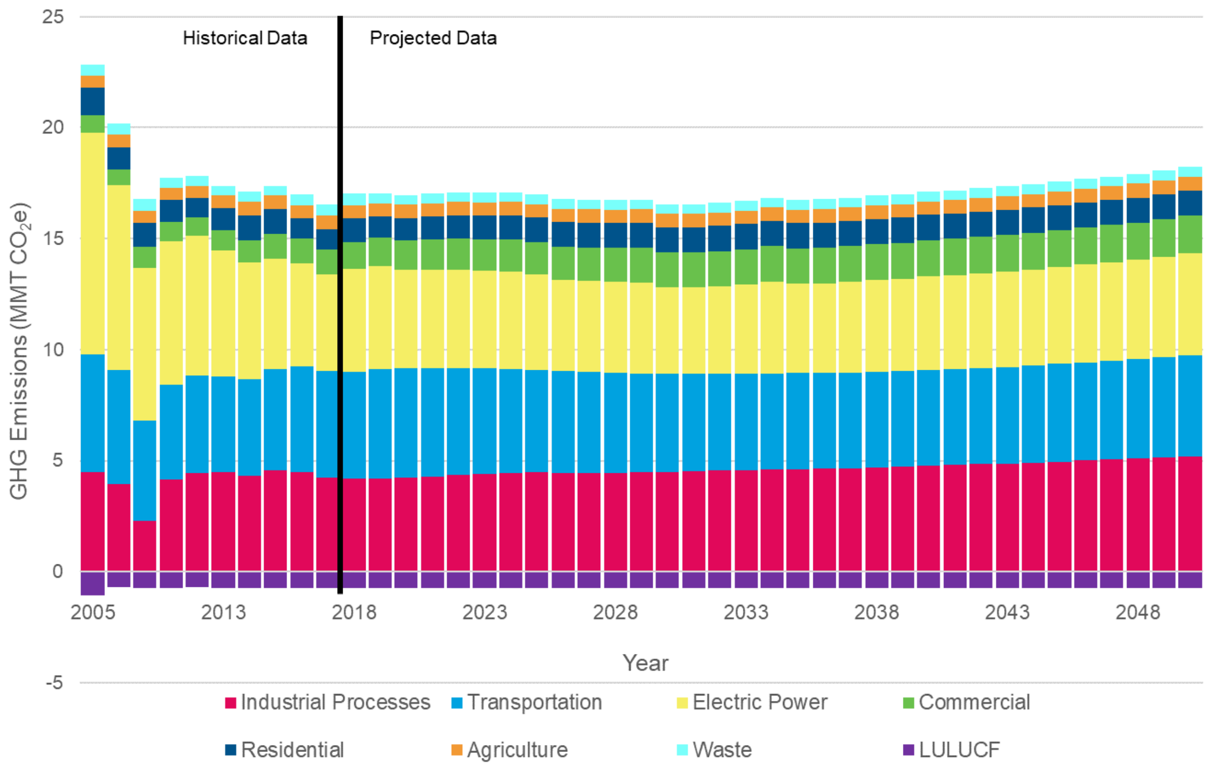


Figure 7. Net BAU Emissions by Greenhouse Gas Through 2050

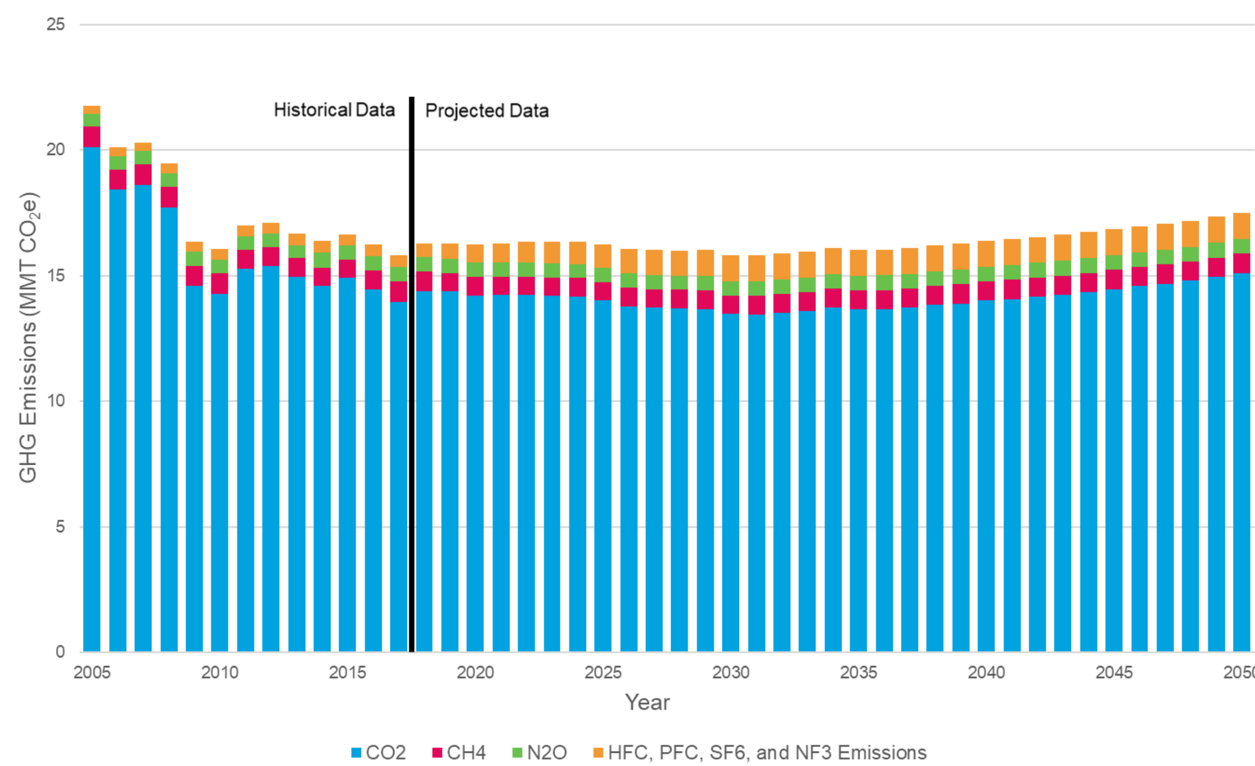
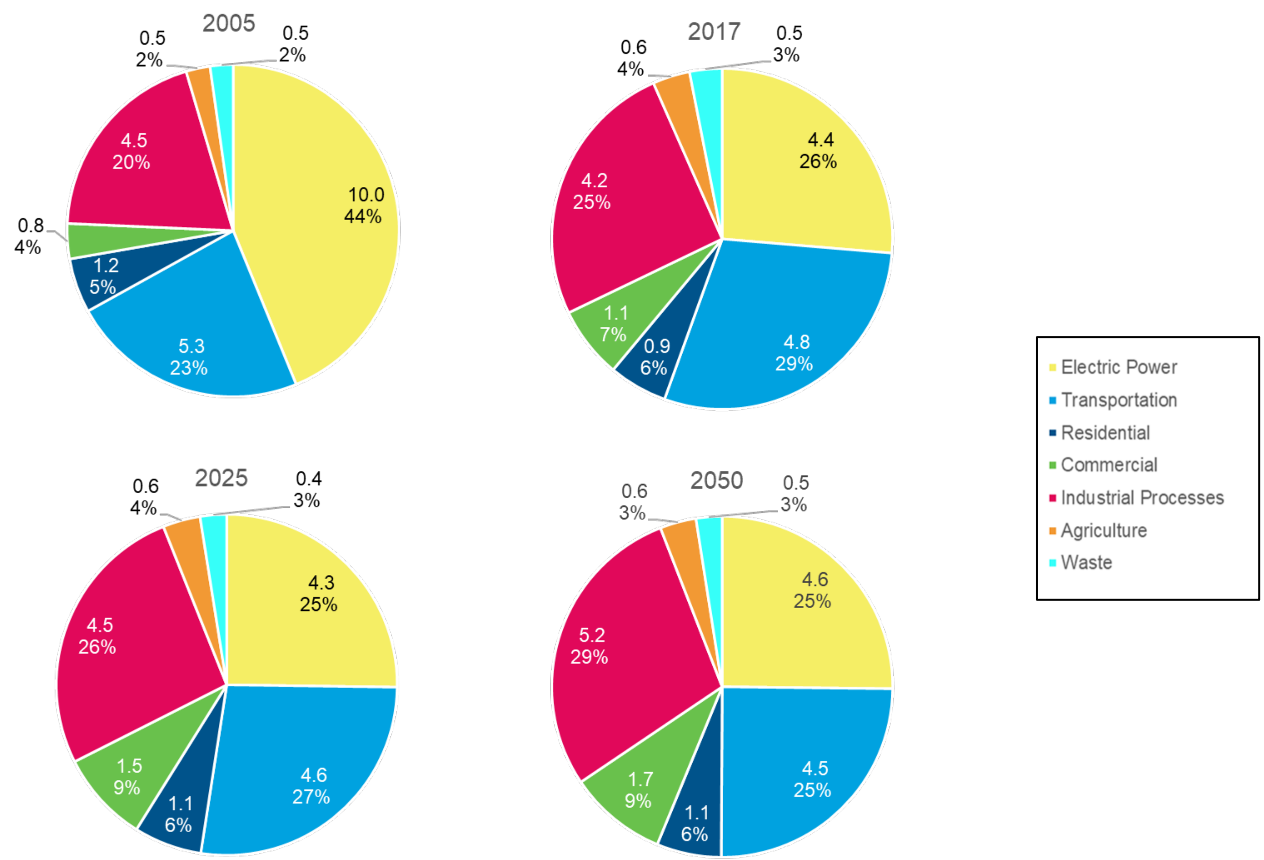


Figure 8 contains four pie charts with the emissions values and the percentage of total annual gross emissions by sector (i.e., not including negative emissions as a result of the LULUCF sector) for 2005, 2017, 2025, and 2050. Figure 8 shows trends in emission shares over time. The year 2017 is included because it is the last year with historical activity data before the BAU projections begin. Between 2005 and 2017, emissions from the electric power sector, which relate to all electricity consumed in the state, decrease from 44% of total emissions to only 26% of total emissions primarily due to the transition of electricity generated from coal with natural gas. Natural gas emits about 40% less GHGs than coal when used as a fuel for generating power (IEA 2020).

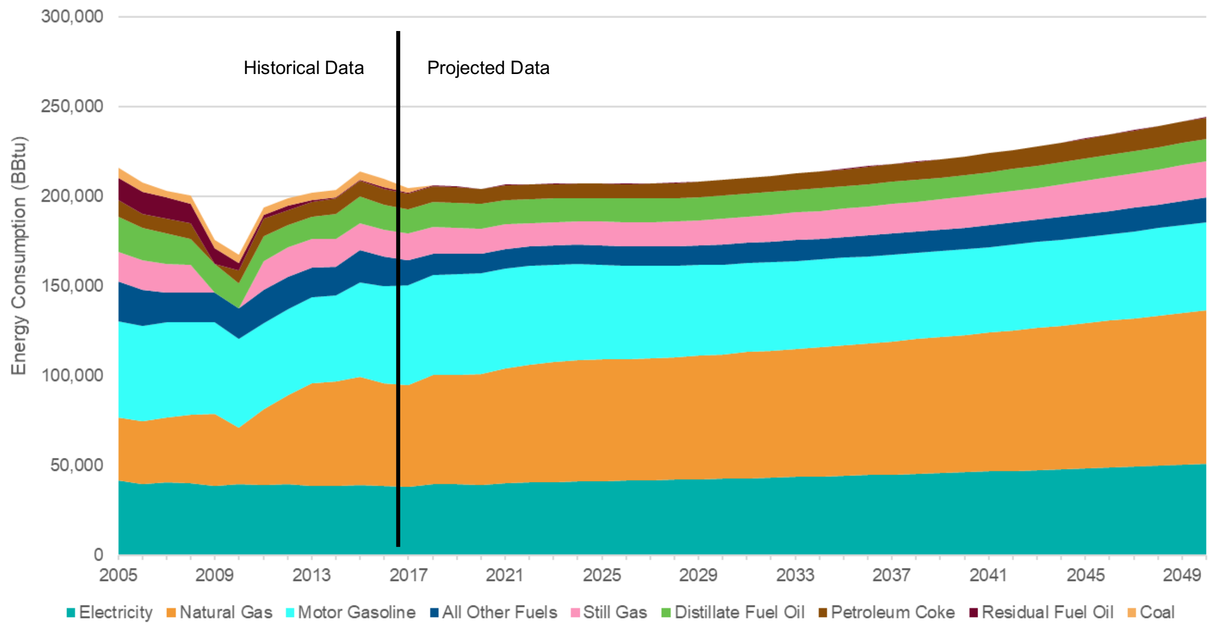
Figure 8. BAU Gross Emissions (MMTCO_2e) and Percent of Total Annual Gross Emissions by Sector for 2005, 2017, 2025, and 2050



The main underlying activity within Delaware that drives GHG emissions is energy use. To that end, Figure 9 shows the total energy consumption by fuel type. The electric power sector represents total electricity consumption, reflecting consumption of electricity generated both in-state and out-of-state electricity. Throughout the time series, electricity, natural gas, and motor gasoline account for the majority of Delaware's energy consumption. From 2005 to 2050, natural gas consumption is projected to grow, in line with the EIA AEO, by 143%, while electricity consumption grows by only 23% and motor gasoline consumption decreases by 9%.[1]

[1] The Safer Affordable Fuel Efficient (SAFE) Vehicles Rule was not included in the BAU or additional analyses as our team used the most recent energy forecast data available from the EIA. The SAFE ruling may impact forecasts for transportation fuel consumption.

Figure 9. Total Gross BAU Energy Consumption by Fuel Type (BBtu)



The supporting data for the above figures is presented in Table 1 and Table 2.

Table 1. Delaware Gross and Net GHG Emissions Summary by Sector (MMT CO_2e), Electric Power Emissions Separated

	Emissions (MMT CO_2e)			Percent change (%)		Percent of total emissions (%)	
Sector	**2005**	**2025**	**2050**	**2005-2025**	**2005-2050**	**2025**	**2050**
Electric Power	10.0	4.3	4.6	-57.2%	-54.1%	25.2%	25.2%
Transportation	5.3	4.6	4.5	-12.5%	-14.1%	27.2%	24.9%
Residential	1.2	1.1	1.1	-9.7%	-7.8%	6.4%	6.1%
Commercial	0.8	1.5	1.7	88.4%	117.7%	8.7%	9.3%
Industrial Processes	4.5	4.5	5.2	-0.5%	15.5%	26.4%	28.5%
Agriculture	0.5	0.6	0.6	12.7%	17.0%	3.6%	3.4%
Waste	0.5	0.4	0.5	-16.4%	-11.8%	2.5%	2.5%
Total	**22.8**	**17.0**	**18.2**	**-25.6%**	**-20.2%**	**100%**	**100%**
LULUCF	(1.1)	(0.7)	(0.7)	-30.9%	-30.9%	NA	NA
Net Total (Sources and Sinks)	**21.8**	**16.3**	**17.5**	**-25.4%**	**-19.6%**	**NA**	**NA**

Table 2. Delaware Net GHG Emissions Summary by Gas (MMT CO_2e)

Gas	Emissions (MMT CO_2e)			Percent change (%)		Percent of total emissions (%)	
	2005	2025	2050	2005-2025	2005-2050	2025	2050
Net CO_2	20.1	14.0	15.1	-30.3%	-24.9%	86.2%	86.3%
CH_4	0.8	0.7	0.8	-9.4%	-6.3%	4.6%	4.4%
N_2O	0.5	0.6	0.6	6.7%	9.8%	3.5%	3.3%
HFC, PFC, SF_6 and NF_3 Emissions	0.3	0.9	1.0	193.3%	227.8%	5.7%	5.9%
Net Total (Sources and Sinks)	**21.8**	**16.3**	**17.5**	**-25.4%**	**-19.6%**	**100%**	**100%**

Key Takeaways

The BAU analysis projects that Delaware will reduce emissions by 25.4% in 2025 and by 19.6% in 2050, relative to 2005 levels, without additional GHG mitigation actions (Table 1.). This means Delaware will come in just under its USCA goal of 26-28% emission reductions by 2025 from 2005 levels without taking additional action. These reductions are consistent with reductions forecasted across various USCA member states with current policies in place, which when combined anticipate reductions from 2005 levels between 20 and 27 percent (U.S. Climate Alliance 2019). Without additional mitigation actions, Delaware's emissions will increase by 7% in 2050 relative to 2025 levels.

The emission reductions observed in the BAU trend are mainly due to a shift from majority coal generated electricity to natural gas generated electricity in the earlier years analyzed. Because burning natural gas as a fuel has an emission rate that is about 40% less than coal, the shift from coal-fired electricity generation to predominantly natural gas-fired electricity generation has historically had a significant impact on Delaware's emissions from electricity consumption. Improvements in vehicle fuel efficiency, improved energy efficiency in residential and commercial buildings, and other state and federal climate policies have also helped Delaware keep on track towards meeting its emissions reduction goals. The state can aim to meet the high end of the USCA goal of 28% reductions by 2025 with additional short-term mitigation actions. In the long-term, the state will need to continue planning and implementing GHG mitigation actions to achieve any future GHG reduction goals it sets.

Specific takeaways with regards to emissions by sector and emissions by gas are noted below.

Emissions by Sector:

- Using the accounting approach described in the box on page 10 above, electric power use (or consumption) is the largest source of emissions and represents nearly half of total emissions in 2005 (45.9%). By 2050, however, it only represents 25.2% of total emissions (Table 1.). This is due to a reduced carbon intensity of the grid, primarily caused by a shift from coal to natural gas and an increase in renewable grid electricity from Delaware's RPS (Table 1.).
- The transportation sector is the second largest emissions source in 2005 (23.1% of total emissions) and the third largest source by 2050 (24.9% of total emissions) (Table 1.).

- The industrial sector is the third largest source of emissions in 2005 (19.7% of total emissions) and grows to become the largest source of emissions in 2050 (28.5% of total emissions) (Table 1.). This is due to a 34.3% increase in industrial energy consumption from 2005 to 2025, largely driven by an increase in natural gas consumption.[2]
- The residential and commercial buildings sectors are the fourth and fifth largest source of emissions in 2005, respectively. By 2050, the two sector switch positions, with emissions from commercial buildings exceeding those from residential buildings. Additionally, HFCs are a significant source of emissions in these sectors, contributing about a quarter to a third of emissions in a given year (Table 1.).

Emissions by Gas:

- Net CO_2 emissions remain the greatest source of emissions by gas from 92.3% in 2005 to 86.3% in 2050, mostly due to fossil fuel combustion (Table 2).
- Emissions of CH_4 and N_2O in 2005 are 2.4% and 1.5% of net emissions, and in 2050 these emissions comprise 4.4% and 3.3% of total emissions, respectively. The majority of CH_4 emissions are from the waste sector and the majority of N_2O emission are from the agricultural sector (Table 2).
- Hydrofluorocarbon (HFC), perfluorocarbon (PFC), sulfur hexafluoride (SF_6), and nitrogen trifluoride (HFC, PFC, SF_6, and NF_3) are high GWP GHGs frequently used as refrigerants or extinguishing agents. Emissions from these gases are projected to more than triple from 1.5% of net emissions in 2005 to 5.9% in 2050. Under the category "HFC, PFC, SF_6 and NF_3 Emissions," HFCs make up almost the entire category as they are the most prominent class of substitutes for ozone-depleting substances and are most commonly used as refrigerants. Effects on these emissions from the state's proposed regulatory actions are not included in the BAU (DNREC 2020a) (Table 2).

BAU Driving Factors

Several factors are driving the trends for the BAU analysis, including shifts in electricity generation, a shift from coal to natural gas in industrial processes, changes in residential energy use, and improved vehicle fuel efficiency. Throughout the time series, the electric power, industrial, transportation, commercial buildings, and residential buildings sectors account for over 90% of total emissions and represent the largest opportunities for emissions reductions. Therefore, actions that can accelerate decarbonization of the grid and that reduce or decarbonize fuel consumption are critical for reducing emissions.

Electricity Generation Shifts: From 2005 to 2025, electricity consumption is projected to decrease by less than 1%. However, emissions from electricity consumption are projected to decrease by 57% (5.7 $MMTCO_2e$) over the same period due to increasing electric power generation from natural gas and renewables and decreasing generation from coal.

- *Shift from Coal to Natural Gas Generation*: In 2005, coal and natural gas respectively accounted for 62% and 20% of Delaware's in-state utility generated electricity. By 2010,

[2] Energy consumption for combined heat and power plants that have a non-regulatory status and small on-site generating systems are attributed to the industrial sector, while energy consumption for combined heat and power plants that have a regulatory status are attributed to the electric power sector, in accordance with AEO2020 reporting by the EIA.

natural gas became the primary source of electricity. By 2025 coal is projected to account for only 2% of Delaware's in-state utility generated electricity while natural gas is projected to account for 89%. This shift is due to economic factors that have made natural gas more economical than coal. This same shift from coal to natural gas electricity generation is happening in the surrounding PJM region mainly driven by economics, leading to decreased emissions from electricity consumption. Because natural gas has approximately 40% the emissions rate of coal, the shift from coal-fired electricity generation to natural gas electricity generation has had a huge impact on Delaware's emissions from electricity consumption. However, as natural gas becomes the leading source of electricity, the marginal benefit in GHG emissions from adding natural gas generating capacity is declining as by 2025 there is very little coal capacity left to replace, and natural gas represents the second most GHG-intensive electricity source next to coal. Natural gas must be replaced by lower carbon or renewable electricity sources for emissions to continue to decline.

- *Increased Renewable Generation:* Because of Delaware's RPS, renewable electricity generation from both in- and out-of-state sources is expected to increase to meet demand. Less than 1% of total electricity consumed in 2005 is met by renewable resources whereas 25% of electricity consumed is projected to be met by renewable resources by 2025.

Industrial Shift from Coal to Natural Gas: From 2005 to 2025, industrial emissions are projected to remain almost constant (only decreasing by less than 1% [0.02 MMTCO_2e]). Despite coal being phased out by 2010 as an industrial emissions source (it accounted for 7% of emissions in 2005), natural gas emissions from the industrial sector more than double between 2005 and 2025.

Residential Energy Use: From 2005 to 2025, residential energy use is projected to decrease by 10% despite a projected increase in population. This decrease of energy use can be partially attributed to an increase in energy efficiency in residential buildings as well as a trend towards warmer winters that will require less energy for heating.

Vehicle Fuel Efficiency Improvements: From 2005 to 2025, transportation emissions are projected to decrease by 13% (0.7 MMTCO_2e), likely due to improved fuel efficiency, as well as increased availability and use of electric vehicles (EVs).

Component 3. Mitigation Actions Selection and Analysis

The third and final component of the of the climate action planning process is to select actions for mitigation modeling and to analyze these actions for their GHG reduction effectiveness and, for some of the selected actions, their costs and economic benefits (i.e., savings). Note that not all potential mitigation actions could be modeled due to resource constraints, therefore the actions modeled below are only a subset of potential actions that could be taken in Delaware. DNREC intends to include these, and other non-modeled actions, for consideration in the final CAP.

Action Selection

ICF and DNREC worked through a rigorous process to identify and select mitigation actions for analysis as outlined below.

Step 1. Identify and Research Potential Actions for Consideration. ICF worked with DNREC to identify and research potential actions to analyze to inform the CAP. DNREC provided an initial potential list of mitigation actions organized by sector to ICF based on programs and actions either planned or implemented. This list was supplemented by ICF with additional actions based on ICF expertise and experience and then categorized by sector/subsector, primary actor, type of action, and expected implementation timeframe. The list of potential mitigation actions was shared with stakeholders at a technical advisory workshop for input, and potential mitigation ideas were collected at public workshops. Feedback from the technical and public workshops was accounted for in the final list of potential mitigation actions.

Step 2. Develop and Apply Criteria for Actions to Model. Informed by ICF's research and experience, DNREC and ICF used the following criteria to select actions to model and potentially include in the CAP:

- GHG Mitigation Effectiveness
- Stakeholder Support
- Initial Investment
- Potential Net Benefits
- Implementation Readiness
- Equity
- Resilience Benefits
- Other Co-Benefits

ICF worked with DNREC to develop relative scoring for each potential mitigation action for the criteria listed above and then aggregated these for a total score for each action. The top five scoring actions for each primary actor and expected timeframe were used to determine the initial list of actions to model. While scoring the mitigation actions, ICF and DNREC placed a higher weight on GHG mitigation effectiveness and implementation readiness. ICF worked with DNREC to finalize the list of mitigation actions to model for GHG reduction potential and cost and savings estimates. In deciding which actions to model, ICF and DNREC focused on: (1) shorter-term actions where existing data and methods were available to quantitatively analyze GHG reductions and/or costs and benefits, and (2) actions that could be bundled into related actions for modeling.

Selection of Mitigation Actions for Analysis

Based on the above outlined process, ICF and DNREC finalized a list of 20 mitigation actions to consider for GHG analysis modeling. The selection process was used to limit the number of actions due to time and budget constraints. This process helped DNREC and ICF come up with a short list of mitigation measures that had the overall highest potential for effective GHG mitigation, implementation readiness, and co-benefits for Delaware.

The actions that ICF and DNREC selected to model are generally well-known as common and successful measures that other states are taking (or are considering taking) and for which information is available to support modeling efforts. For some of the non-selected actions, such as those related to emerging mitigation technologies, data are not readily available and therefore could not be modeled or required assumptions to bridge data gaps. The list of actions selected for modeling is described in the following section.

List of Mitigation Actions Selected for Analysis

Below is the list of actions selected for GHG reduction analysis. More detailed explanations of each are provided in the following summaries (see "Methodology and Results for Modeled Actions"). Actions are grouped by category, which include distributed grid (DG), energy efficiency (EE), high global warming potential (HIGH-GWP), natural gas (NG), transportation (TPORT), and waste (WASTE). The corresponding number reflects the count of total measures in each category, not necessarily the importance or reduction potential of each action. Some of these actions consist of similar or complementary strategies that are bundled into a comprehensive action, while other actions consist of one specific action.

- **DG-1: Expanded Renewable Energy On-site (Residential and Commercial).** Installation of renewable energy on-site at residential and commercial buildings. This includes energy storage and grid integration (peak demand reduction) and expansion of the low-income housing solar energy program.
- **DG-2: Expanded Renewable Energy On-site (Industrial).** Installation of renewable energy on-site at industrial facilities, including energy storage and grid integration to facilitate peak demand reduction.
- **EE-1: Expanded Building Energy Codes**. Expansion of the current building energy codes in Delaware to increase energy efficiency.
- **EE-2: Expanded Residential Energy Efficiency Programs**. Expansion of existing residential energy efficiency programs in Delaware.
- **EE-3: Building Electrification**. Retrofits of existing buildings to replace fossil fuel systems and appliances with electric and requirements for building electrification for new constructions.
- **EE-4: Expanded Commercial Energy Efficiency Programs**. Development and/or expansion of commercial building energy efficiency programs in Delaware.
- **EE-5: Industrial Energy Efficiency Improvements**. Improvements to industrial lighting systems, motor systems, air compressors, materials handling equipment, process improvements, and operational reviews and improvements.
- **GRID-1: Expanded Renewable Portfolio Standard (RPS)**. Expansion of the RPS in Delaware, with the targets of 25% renewable electricity from the grid by 2025, 40% by 2035, and 100% by 2050.
- **HIGH-GWP-1: Reduce Commercial Building High-Global Warming Potential Emissions**. Expansions and use of Delaware's Cool Switch program and implementation of Regulation 1151.
- **HIGH-GWP-2: Reduce Industrial High-GWP Emissions**. Expansion of the use of low-GWP refrigerants and reduce high-GWP refrigerant emissions in the industrial sector by implementing Cool Switch and Regulation 1151, and implementation of programs to manage HFCs and other high-GWP materials throughout the product lifecycle.

- **NG-1: Methane Emission Reductions from Utility Gas Lines.** Implementation of a Leak Detection and Repair (LDAR) program for utility gas lines; includes a requirement for all utility gas lines to undergo LDAR inspections.
- **TPORT-1: Low Carbon Fuel Standard.** Implementation of a Low Carbon Fuel Standard (LCFS) to incentivize and increase the implementation of low carbon fuels, based on the California Air Resources Board (CARB) program.
- **TPORT-2: Light-Duty Vehicle Travel Demand Management and Land Use Strategies**. Reduction of vehicle miles traveled of private passenger vehicles by implementing travel demand strategies such as shifting travel time, mode choice, and route and increasing frequency of telecommuting. These efforts would be paired with land use and development policies.
- **TPORT-3: Vehicle Manufacturer Regulations**. Implementation of regulations requiring vehicle manufacturers to make available specific quantities of light-duty zero emission vehicles (ZEVs), including electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and hydrogen fuel cell vehicles.
- **TPORT-4: Consumer Electric Vehicle Adoption Incentives**. Creation of a program to advance EV adoption through increased infrastructure, incentive programs, charging rate plans, and legislation.
- **TPORT-5: State Fleet Electrification.** Electrification of the state's vehicle fleet. State agencies are projected to increase the number of ZEVs in light-duty fleets to at least 20% of the fleet by 2025, and to 100% by 2050.
- **TPORT-6: Fuel-Efficient Vehicles**. Implementation of incentive programs and consumer outreach to expand adoption of more fuel-efficient gasoline-powered private passenger vehicles.
- **TPORT-7: Expand Freight Best Practices and Regulatory Actions**. Expansion of freight best practices for fuel efficiency and emission reductions including mode switching, route optimization, emissions regulations, and efficiency standards.
- **WASTE-1: Expanded Methane Capture**. Reduction of methane emissions through improved controls and monitoring and expanded methane capture for Renewable Natural Gas (RNG) supply or flaring.
- **WASTE-2: Waste Diversion and Reduction**. Diversion of waste from landfills through increased recycling and organic waste diversion (composting, land application, animal feed, etc.).

A subset of these actions was selected for *economic* modeling. The number of actions that could be modeled for economic benefit was limited by time and budget. These actions were selected because they build upon existing state programs and data was readily available. The actions selected for cost analysis were:

- DG-1: Expanded Renewable Energy On-site (Residential and Commercial)
- DG-2: Expanded Renewable Energy On-site (Industrial)
- EE-1: Expanded Building Energy Codes
- EE-2: Expanded Residential Energy Efficiency Programs
- EE-4: Expanded Commercial Energy Efficiency Programs
- GRID-1: Calculations for Expanded Renewable Portfolio Standard (RPS)
- TPORT-4: Consumer Electric Vehicle Adoption Incentives

Analysis

ICF analyzed each of the above recommended mitigation actions to include estimated GHG reductions for all actions and implementation costs and savings for a selection of actions. Similar to the BAU, ICF uses a GHG accounting approach incorporating both in state and out of state electricity. By employing a holistic accounting framework, ICF avoided overlapping GHG reductions from different sectors and mitigation actions (i.e., “double counting”).

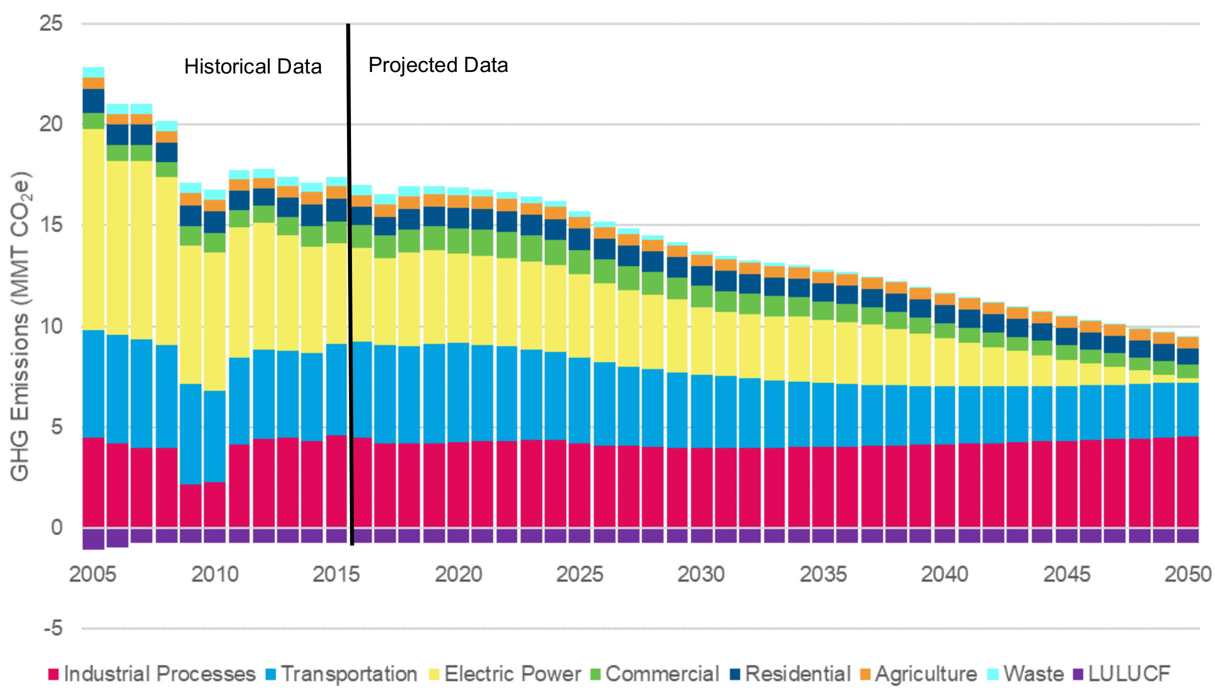
ICF evaluated where double counting may occur and then “layered” mitigation actions to avoid double counting emission reductions actions that interact with others. ICF layered mitigation actions by including assumptions about their implementation order, particularly in the Energy and Transportation sectors. For example, an advanced RPS (GRID-1) would reduce emissions from Delaware’s electricity sector through increasing use of low-carbon energy sources, and these reductions are reflected in the GRID-1 action. As a result, related measures, such as electric vehicle adoption (TPORT-4) are layered on top of the advanced RPS by using GRID-1 as a starting point for calculating emission reductions. This means that TPORT-4 reflects emissions reduced through vehicle efficiency improvements, and not emission reductions from increased renewable electricity generation to avoid double counting with GRID-1. Details and results of the analysis for each recommended action can be found below, under Methodology and Results for Modeled Actions.

For the actions selected for economic modeling, the net present value (NPV) of the action was calculated. NPV represents the current economic value of all future costs and benefits. This is calculated by estimating future costs and savings and applying a discount rate (2.4% based on Office of Management and Budget [OMB 2019] guidance) to represent the current value of those costs and benefits. A positive NPV indicates that the value of the action is a net cost, while a negative NPV indicates a net benefit. For example, mitigation action EE-1 has an NPV of ($870.7 million); this means the action will save $870.7 million in today’s currency after netting the value of all future costs and benefits. Whereas DG-1 has an NPV of $1.1 billion; this means the action will cost $1.1 billion in today’s currency after netting the value of all future costs and benefits.

Key Takeaways

The comprehensive GHG mitigation analysis of all of the above recommended actions indicates **net GHG emissions (including sources and sinks) in Delaware will decline from 2005 levels by 31.1% in 2025 and by 59.7% in 2050 if all 20 GHG mitigation actions were implemented**. By implementing the mitigation actions modeled in the analysis, Delaware can exceed its goal of 26-28% emissions reductions by 2025 and achieve 31.1% GHG reductions from 2005 levels (a reduction of 6.8 MMT CO_2e). Furthermore, by implementing all of the selected mitigation actions, Delaware is projected to decrease emissions by an additional 5.7% and 40.1% more than in the BAU scenario by 2025 and 2050, respectively (a further reduction of 1.26 and 8.73 MMT CO_2e) (Figure 10).

Figure 10. GHG Mitigation Action Analysis Results for 2005-2050



High-Impact Results

The results of the analysis indicate there are three high-impact mitigation actions.

1. **Decarbonization of the electricity grid has the highest emission reduction potential in the medium- and long-terms and drives emission reductions for many other actions.** The greatest mid- and long-term driver of emission reductions in the mitigation scenario analysis results from the RPS expansion action, which increases the portion of renewable electricity over time. Estimated GHG emission reductions from buildings and transportation electrification are dependent on acceleration of the grid decarbonization through the expanded RPS. Additionally, the RPS helps amplify reductions from energy efficiency actions. A significant portion of estimated emission reductions in the electric power, transportation, commercial buildings, residential buildings, and industrial processes sectors rely on accelerating decarbonization of the electricity grid.

2. **Electrification of buildings and vehicles presents an opportunity to capture large emission reductions.** Vehicle and building electrification actions are both large drivers of emission reductions, but they rely on the grid decarbonizing from the expanded RPS for full effectiveness.
3. **Energy efficiency actions are very impactful in the short-term and are low cost.** Energy efficiency actions are highly effective, particularly before the grid significantly decarbonizes from the RPS expansion (pre-2035). Energy efficiency actions are some of the lowest cost actions, with some actions resulting in cost savings.

Key Terms in Emission Reductions

Decarbonization: Long-term strategies to reduce CO_2 emissions by phasing out the use of carbon-emitting processes and technologies, primarily by eliminating the combustion of fossil fuels as an energy source, with the end goal of a carbon-free global economy.

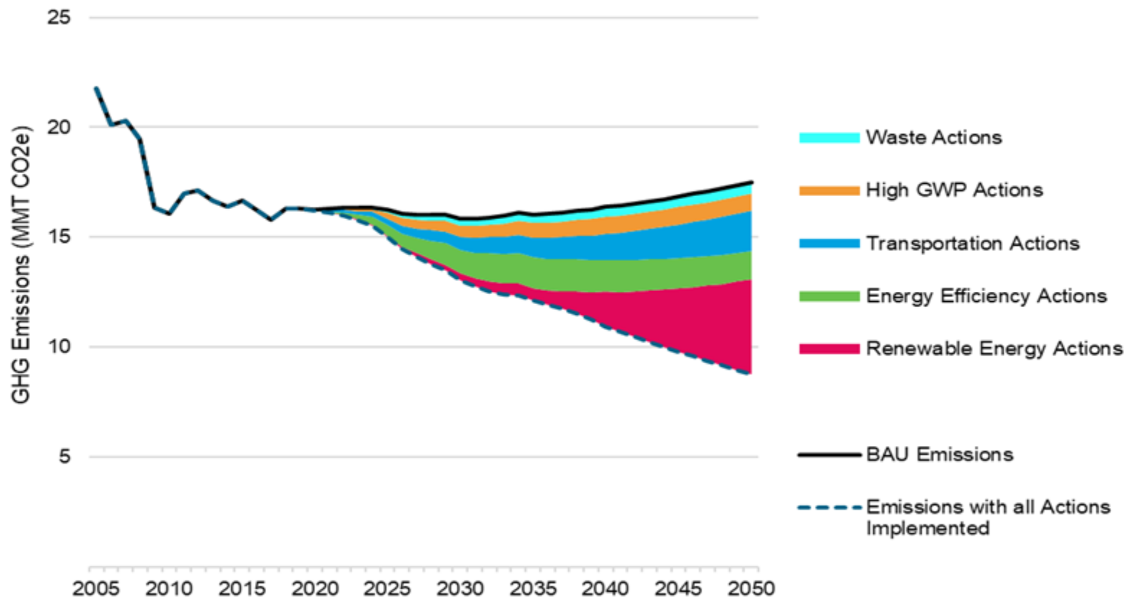
Electrification: The process of replacing technologies that use fossil fuels as an energy source with technologies that use electricity instead, with the expectation that the electricity is generated using a cleaner energy mix. For example, by electrifying cars, gasoline and diesel-powered engines are replaced with batteries powered by electricity from the grid, which likely includes a mix of renewable and/or clean energy sources that result in less GHG emissions than burning gasoline.

Energy Efficiency: The replacement of older or less energy efficient appliances, vehicles, building materials, and other technologies with newer, more efficient designs that require less energy. Efficiency improvements can provide both emission and cost savings in the short-term.

Together, decarbonization, electrification, and energy efficiency interact closely as major drivers of emission reductions. Efficiency improvements reduce energy demand, electrification drives efficiency and creates opportunity to shift to potentially cleaner energy sources via renewable electricity, and decarbonization reduces emissions from energy.

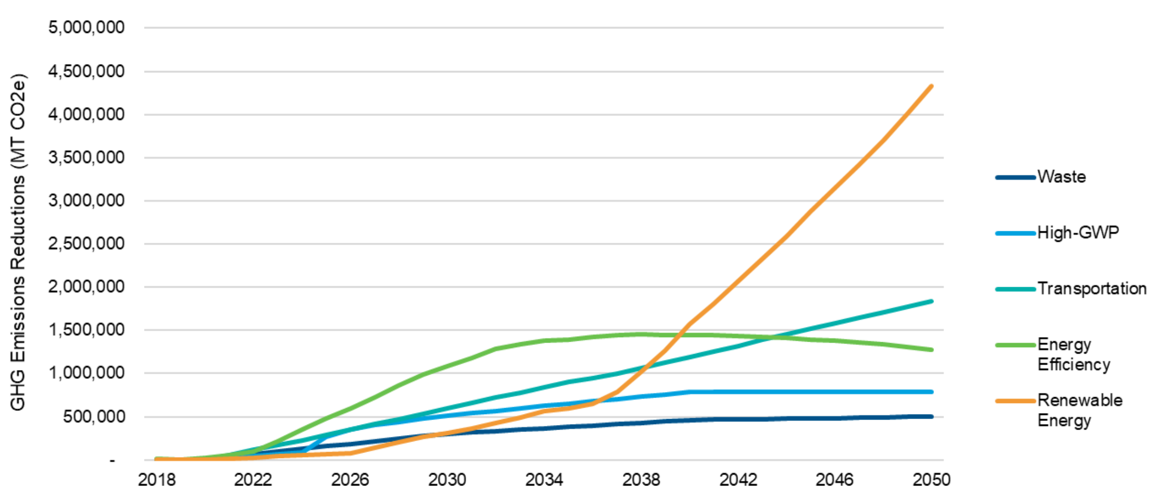
The GHG mitigation scenario projections through 2050 offer Delaware an emissions trajectory that can be used to inform setting long-term climate goals. The analysis indicates that implementation of the modeled mitigation actions would result in a 59.7% reduction in GHG emissions from 2005 levels in 2050. The GHG mitigation analysis can also be examined in terms of types of action. Again, this just represents a subset of high impact actions for GHG emission reductions that Delaware can take. Mitigation actions were grouped into the following “type” categories: Waste (WASTE-1 and -2), High GWP (HIGH-GWP-1 and -2, Natural Gas (NG-1), Transportation (TPORT-1 through -7), Energy Efficiency (EE-1 through -5), and renewable energy (GRID-1 and DG-1 and -2). Figure 11 shows results of the mitigation analysis by category.

Figure 11. Net GHG Emissions Mitigation (MMTCO_2e) by Mitigation Action Category



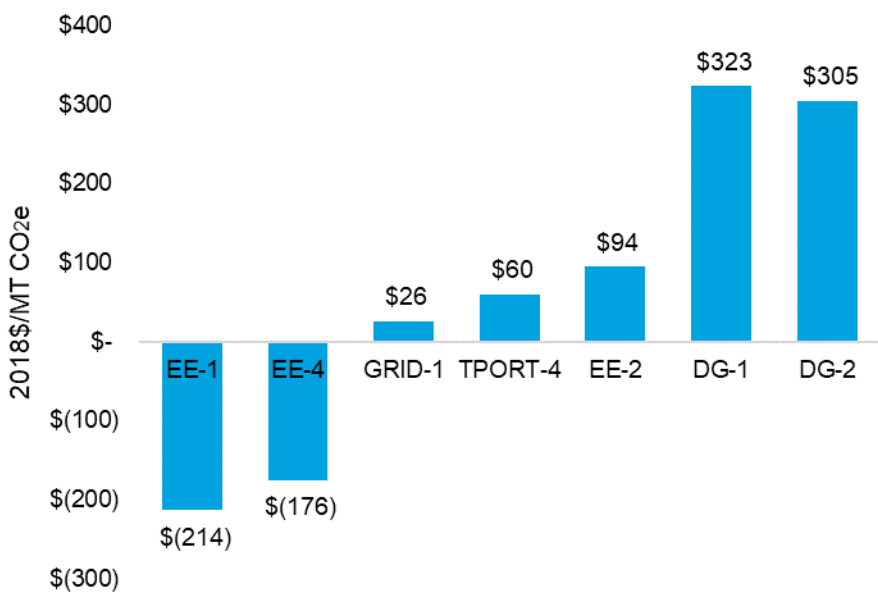
Mitigation actions have varying levels of effectiveness over extended time periods. Actions typically become more effective over time for many reasons, including increased adoption rates, technology advances, reduced costs, and other factors. Under this modeling framework, different mitigation actions are assumed to begin implementation at different times. For example, Delaware is likely unable to implement a Low Carbon Fuel Standard (LCFS) before 2025 but can continue implementation of the Cool Switch—Low Impact Refrigerant Program in 2020. Figure 12 demonstrates the GHG emissions reductions of different action categories over time. Each category becomes increasingly effective over time, though the effectiveness of energy efficiency actions eventually decline, and others see reduced marginal gains after a certain point. Renewable energy actions are less effective than other actions in the near term due to slower ramp up, but in the medium and long term are by far the most effective.

Figure 12. Gross GHG Emissions Reductions by Mitigation Category



In addition to the temporal impacts of different actions, costs are an important consideration for planning and implementing mitigation actions. ICF modeled 7 of the 20 actions for costs and savings, based on readily available data and information. The results of the cost and savings analysis for the subset of actions is provided in Figure 13. The actions with negative values have economic greater benefits than costs, i.e., action EE-1 results in savings of $214 for every metric ton of CO_2e reduced. The energy efficiency actions result in savings because energy efficiency technology is advanced and relatively inexpensive, and the resulting savings can be significant. Whereas the relatively higher costs per ton of actions DG-1 and DG-2 reflect the fact that those actions require most investment and result in relatively less or no savings over time. These cost estimates should be considered high-level and indicative. In-depth cost analyses may be beneficial for various actions separate from this analysis as the State considers moving into either policy or program design or implementation of a CAP.

Figure 13. Cost (Benefit) per Metric Ton of Gross CO_2e Reduced, by GHG Mitigation Action



Methodology and Results for Modeled Actions

The following pages provide descriptions of the methodology and results for modeled actions. The GHG reduction results presented below represent a projected reduction in a given year as compared to BAU emissions. All results incorporate accounting for both in-state and out-of-state electricity generated.

DG-1: Expanded Renewable Energy On-site (Residential and Commercial)

Annual gross emission reduction compared to BAU in 2025:	65,500 $MTCO_2e$
In 2035:	167,700 $MTCO_2e$
In 2050:	25,900 $MTCO_2e$
Expected benefits	Air quality, employment, energy supply resilience
Net Present Value	$1.1 billion
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	$323 / MTCO2e

Mitigation action DG-1 refers to the installation of renewable energy on-site at residential and commercial buildings. This includes energy storage and grid integration (peak demand reduction) and expansion of the low-income housing solar energy program.

Methodology and assumptions: ICF estimated the amount of energy generated by on-site renewable energy by applying electricity emission factors to estimates of aggregated capacity installed for residential and commercial photovoltaic (PV) systems. ICF assumed that 25% of residential homes and 15% of commercial spaces would have on-site renewable installations by 2050. Next, ICF linearly interpolated the percentage of existing residential and commercial buildings with on-site renewables through 2050, assuming a baseline of zero in 2020, to estimate annual capacity. Assumed values for solar PV system capacity, cost information, and degradation rates were based on data from the National Renewable Energy Laboratory (NREL). The number of homes was assumed to grow after 2018 based on population growth. The square footage of commercial buildings available for on-site solar is assumed to be Delaware's population percentage applied to the total South Atlantic commercial buildings' square footage from Commercial Buildings Energy Consumption Survey (CBECS) and scaled to 2018. Additional PV system information was used from Solar Estimate and Best Contracting.

Measure is impacted by: Expanded RPS (GRID-1)

Expected benefits: In addition to reducing GHG emissions, on-site renewable energy systems can improve air quality by reducing demand for fossil fuel fired electric power generation. They can also provide employment opportunities. On-site renewable energy systems benefit resilience by diversifying energy sources; resilience benefits from on-site energy sources can be expanded when coupled with local electricity storage. Expanding renewable energy requires capital costs for system purchase and installation, as well as operations and maintenance costs. Costs associated with on-site residential and commercial systems are expected to decline due to increased adoption and economies of scale.

Economic methodology and assumptions: ICF estimated the cost of installing and maintaining on-site renewable energy for the residential and commercial sectors using an average system lifetime value. Assumptions include PV system lifetime, inflation rate, capital costs of residential and commercial PV installations ($2,770/kW for residential systems and $1,857/kW for commercial in 2019), and annual operating and maintenance costs ($24/kW for residential and $18/kW for commercial in 2019) based on data from NREL.[3]

[3] https://atb.nrel.gov/electricity/2019/data.html

DG-2: Expanded Renewable Energy On-Site (Industrial)

Annual gross emission reduction compared to BAU in 2025:	2,700 MTCO2e
In 2035:	6,200 MTCO2e
In 2050:	820 MTCO2e
Expected benefits	Air quality, employment, energy supply resilience
Net Present Value	$38.2 million
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	$305 / MTCO2e

Mitigation action DG-2 includes installing renewable energy on-site at industrial facilities, including energy storage and grid integration to facilitate peak demand reduction.

Methodology and assumptions: ICF estimated the amount of energy generated by on-site renewable energy by applying electricity emission factors to estimates of aggregated capacity installed for industrial PV systems. ICF assumed that 15% of industrial spaces would have on-site renewable installations by 2050. Next, ICF linearly interpolated the percentage of industrial sites with on-site renewables through 2050 and applied degradation factors annually for aging systems. Values for solar PV system cost and degradation were taken from NREL, and the average capacity and square footage of an industrial solar PV system was based on the average of all of Massachusetts' systems in their Production Tracking System, which represented the most relevant and complete data source for estimating performance for this specific action.

Measure is impacted by: Expanded RPS (GRID-1)

Expected benefits: In addition to reducing GHG emissions, on-site renewable energy systems are expected to improve air quality by reducing demand for fossil fuel fired electric power generation. It can also provide employment opportunities and resilience benefits by diversifying energy sources. Resilience benefits from on-site energy sources can be expanded when coupled with local electricity storage. Implementation of this measure will require capital costs including the cost of systems and installation, as well as operating and maintenance costs. The cost of on-site renewable energy systems is expected to decline over time due to increased adoption and economies of scale.

Economic methodology and assumptions: ICF estimated the cost of installing and maintaining on-site renewable energy for the industrial sector, using an average system lifetime value. Assumptions included PV system lifetime, inflation rate, capital costs of residential and commercial PV installations ($1,857/kW), and annual operating and maintenance costs ($18/kW) based on NREL data.[4]

[4] For both DG-1 and DG-2, distribution utilities may have some costs to accommodate increased distributed resources and electrification, but these are not included in the economic assessment.

EE-1: Expanded Building Energy Codes

Annual gross emission reduction compared to BAU in 2025:	35,100 $MTCO_2e$
In 2035:	164,800 $MTCO_2e$
In 2050:	134,500 $MTCO_2e$
Expected benefits	Employment, air quality, energy supply resilience
Net Present Value	($870.7 million)
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	($214) / MTCO2e

Mitigation action EE-1 includes expanding the current building energy codes in Delaware to increase energy efficiency. Under this measure, building energy codes would be altered to include the net-zero residential and commercial appendices in the 2021 International Energy Conservation Code (IECC) (i.e., continued 16 Del. C. §7602 implementation), projected stringency increases in future IECC and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards, and a requirement for EV-friendly buildings. Additionally, this measure would increase code enforcement and compliance and improve baseline energy code compliance with model energy codes.

Methodology and assumptions: Using the ICF Energy Code Calculator, ICF projected implementation of updates to the IECC and ASHRAE code versions every six years through 2050 for residential and commercial buildings. ICF used linear interpolation to estimate the ramp-up of net-zero net energy residential and commercial buildings and assumed an IECC 2012 base code and ASHRAE 2010 base code for residential and commercial buildings, respectively. 90% compliance was assumed for all new construction and renovations.

Measure is impacted by: Expanded RPS (GRID-1)

Expected benefits: This measure is expected to reduce GHG emissions as a result of electricity and gas savings. The expansion of building energy codes could also lead to improved air quality at energy/electricity generation sites through reduced generation requirements and create new employment opportunities. Additionally, increased resource efficiency benefits energy supply resilience.

Economic methodology and assumptions: Expanding energy building codes will improve energy efficiency, which in turn reduces energy costs in residential and commercial buildings. To calculate the costs and savings associated with code compliance and updates ICF assumed incremental costs for residential ($/home) and commercial ($/square foot) construction, which were applied to the number of renovations and newly constructed homes and new commercial square footage, respectively, each year in the time series.

EE-2: Building Electrification

Mitigation action EE-2 includes retrofitting existing buildings and requiring building electrification in new construction.

Annual gross emission reduction compared to BAU in 2025:	45,800 MTCO2e
In 2035:	170,600 MTCO2e
In 2050:	545,700 MTCO2e
Expected benefits	Air quality, employment
Net Present Value	$609.9 million
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	$94 / MTCO2e

Methodology and assumptions: ICF applied an average annual energy savings potential for residential and commercial buildings to evaluate energy consumption (natural gas) reductions from electrification of existing buildings and the amount of electricity required to replace that use of natural gas. ICF assumed that 25% of residential and 40% of commercial buildings are retrofitted to be all-electric by 2050, and that 90% of new residential and commercial buildings are all-electric by 2050.

Measure is impacted by: Expanded RPS (GRID-1)

Expected benefits: When coupled with a cleaner grid this measure is expected to reduce GHG emissions associated with energy used to operate homes and businesses. Building electrification could also lead to improved air quality around and within homes and business due to reduced on-site fossil fuel use and create new employment opportunities.

Economic methodology and assumptions: ICF estimated differences in the costs of constructing all-electric residential and commercial buildings compared to buildings that require electricity and natural gas. ICF also estimated differences the costs for retrofitting buildings to be all-electric compared to the costs associated with buildings that use electricity and natural gas in the residential sector. Assumptions for commercial buildings included incremental costs of heating and domestic hot water retrofits and the incremental cost for new electric buildings. Assumptions for residential buildings included new building and retrofit costs for electric end-use appliances and costs for natural gas end-use appliances. (e.g., furnace, air conditioner).

EE-3: Expanded Residential EE Programs

Mitigation action EE-3 includes the expansion of residential energy efficiency programs such as the Sustainable Energy Utility (SEU), Delaware State Housing Authority programs such as Replace or Repair Heaters and Conserve Energy (RRHACE), the Low-Income Home Energy Assistance Program (LIHEAP), the Weatherization Assistance Program (WAP), and ongoing evaluation, measurement, and verification.

Annual gross emission reduction compared to BAU in 2025:	123,900 $MTCO_2e$
In 2035:	315,000 $MTCO_2e$
In 2050:	104,000 $MTCO_2e$
Expected benefits	Employment, air quality, energy supply resilience
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

Methodology and assumptions: ICF applied an average annual energy efficiency potential for electricity and natural gas for the residential sector to estimate energy savings. Next, ICF applied electricity and natural gas emission factors to energy savings. For these calculations, ICF assumed that energy consumption in residential buildings will decrease by 0.7% annually as a result of expanded residential EE programs from 2020-2022, and by 1.5% annually from 2023 forward. This follows the methodology used to project building energy/natural gas consumption in the Arlington Community Energy Plan.[5] The energy efficiency potential was based on Delaware's SEU report participation data.

Measure is impacted by: Expanded RPS (GRID-1); Expanded Building Codes (EE-1)

Expected benefits: In addition to reducing GHG emissions, this measure is expected to improve air quality at energy/electricity generation sites through reduced generation requirements and provide employment opportunities. It can also improve resilience because resource efficiency improves energy supply resilience. This measure can provide climate resilience benefits by expanding on low-income energy efficiency programs, providing greater energy security for populations that may be more vulnerable to climate impacts such as increasing temperatures and extreme heat events.

[5] This measure and EE-5 utilize modeling approaches and assumptions from the recent Arlington Community Energy Plan that focuses on energy efficiency improvement programs (Arlington County 2019).

EE-4: Expanded Commercial Energy Efficiency Programs

Annual gross emission reduction compared to BAU in 2025:	127,700 $MTCO_2e$
In 2035:	317,700 $MTCO_2e$
In 2050:	114,600 $MTCO_2e$
Expected benefits	Air quality, employment, energy supply resilience
Net Present Value	($1.125 billion)
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	($176) / $MTCO_2e$

Mitigation action EE-4 includes the development and/or expansion of commercial building energy efficiency programs in Delaware.

Methodology and assumptions: ICF applied an average annual energy efficiency potential for electricity and natural gas for the commercial sector to estimate energy savings. ICF then applied electricity and natural gas emission factors to energy savings. For these calculations, ICF assumed that energy consumption in commercial buildings will decrease by 0.7% annually as a result of expanded commercial EE programs from 2020-2022, and by 1.5% annually from 2023 forward.

Measure is impacted by: Expanded RPS (GRID-1); Expanded Building Codes (EE-1)

Expected benefits: This mitigation measure is expected to improve air quality at energy/electricity generation sites through reduced generation requirements and provide new employment opportunities, in addition to mitigating GHG emissions. It is also expected to improve resiliency, as resource efficiency is beneficial for energy supply resilience.

Economic methodology and assumptions: To calculate costs for this measure, ICF applied a $0.35/therm levelized cost of saved energy from ACEEE's Review of the Cost of Utility Energy Efficiency Programs annually from 2020-2050. Levelized cost of saved energy includes direct program costs like incentives, as well as measure installation, program design and administration, marketing, education, evaluation, and shareholder incentives/performance fees.

EE-5: Industrial Energy Efficiency Improvements

Annual gross emission reduction compared to BAU in 2025:	146,200 $MTCO_2e$
In 2035:	427,900 $MTCO_2e$
In 2050:	379,000 $MTCO_2e$
Expected benefits	Employment, air quality, energy supply resilience
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

Mitigation action EE-5 would improve industrial energy efficiency through improvements to lighting systems, motor systems, air compressors, materials handling equipment, process improvements, and operational reviews and improvements (e.g., reducing operating hours for specific equipment, outreach, and training).

Methodology and assumptions: ICF estimated energy savings by applying an average annual energy efficiency potential for electricity and natural gas for the industrial sector to evaluate energy consumption reductions. Reduced energy consumption was used to estimate GHG mitigation potential. For these calculations, ICF assumed that energy consumption in industrial facilities will decrease by 0.7% annually as a result of expanded industrial EE programs from 2020-2022, and by 1.5% annually from 2023 forward.

Measure is impacted by: Expanded RPS (GRID-1)

Expected benefits: In addition to reducing GHG emissions from industrial operations, this measure is expected to improve air quality at energy/electricity generation sites through reduced generation requirements sites and provide employment opportunities. It would also increase resilience because resource efficiency benefits energy supply resilience.

GRID-1: Calculations for Expanded Renewable Portfolio Standard

Annual gross emission reduction compared to BAU in 2025:	None
In 2035:	421,700 $MTCO_2e$
In 2050:	4,306,500 $MTCO_2e$
Expected benefits	Air quality, employment
Net Present Value	$932.5 million
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	$26 / MTCO2e

This mitigation action focuses on expanding the RPS in Delaware, with the targets of 25% renewable electricity from the grid by 2025, 40% by 2035, and 100% by 2050.

Methodology and assumptions: ICF updated electricity emission factors changes based on the Renewable Energy Portfolio Standards Act (REPSA) (i.e., 25% renewable energy by 2025). ICF adjusted emission factors by applying the ratio of the expected proportion of nonrenewable energy in the grid mix to the 2017 proportion of nonrenewable energy in the grid mix. Every year's target is a June 20XX-June 20XX+1 target. To reconcile this with the Jan-Dec annual modeling, and to be conservative, ICF made a June 2025-June 2026 target occur in 2026.

Measure is impacted by: Not impacted by other measures

Expected benefits: In addition to significantly reducing GHG emissions, the expanded RPS in Delaware is expected to improve air quality and provide employment opportunities.

Economic methodology and assumptions: ICF calculated the incremental cost of the RPS program expansion as the difference in REC payments between a Base Case with no RPS expansion and the Expansion Case. ICF used its off-the-shelf price forecast of REC prices for Delaware, which represent the make-whole value between the cost to build renewables and the market revenues they receive.

For the Expansion Case, ICF assumed, based on market projections, that part of Delaware's compliance would come from offshore wind procurements. For simplicity and modeling purposes, beginning in 2030, ICF assumed 50% of the RPS demand will be satisfied by offshore wind. ICF selected 50% compliance based on the relative size of offshore wind mandates in neighboring states. The rest of the incremental need is met through utility-scale solar additions. Offshore wind and solar were selected to mirror similar coastal states in the Northeast. With the Production Tax Credit phasing out in 2024, utility-scale solar has a lower levelized cost of energy than onshore wind in PJM, which is why ICF assumed that would be the selected resource. ICF included a sensitivity analysis without offshore wind that assumes only solar purchases are made to satisfy demand increases.

ICF also conducted a high-level cost analysis showing one example of a compliance pathway using projected offshore wind costs, and what programmatic resources might be needed in terms of offshore wind incentives. Since only one pathway was evaluated for this assessment, DNREC might consider conducting additional economic assessments in the future specifically geared to RPS costs to better determine the costs of different implementation pathways.

HIGH-GWP-1: Reduce Commercial Building High-GWP Emissions

Annual gross emission reduction compared to BAU in 2025:	108,500 $MTCO_2e$
In 2035:	374,700 $MTCO_2e$
In 2050:	499,700 $MTCO_2e$
Expected benefits	Improved safety and energy efficiency
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

Mitigation action HIGH-GWP-1 refers to reducing HFC emissions in the commercial building sector, through the implementation of a combination of regulatory and voluntary programs. If fully implemented, use of high-GWP (>1,500) refrigerants will be reduced by 100% by 2040.

Methodology and assumptions: First, ICF linearly forecasted participation in the Cool Switch program based on assumptions from historical data. Then, ICF added an additional target of 100% phase down of high-GWP refrigerants in the commercial sector by 2040 through the implementation of the proposed regulation 1151 and additional federal or state-level policies. GHG emissions reduction from the Cool Switch program was calculated first in modeling for each year, then ICF linearly interpolated the yearly reduction requirements from complementary policies to meet the selected 2040 target. Finally, ICF applied reduction efficiency values for commercial refrigeration systems and air-conditioning equipment to determine the potential for HFC mitigation based on differences in GWP from original refrigerants and alternatives. For these calculations, ICF assumed 100% Cool Switch participation by 2040.

Measure is impacted by: None

Expected benefits: This measure will reduce emissions of high-GWP gases; it will also improve safety and energy efficiency.

HIGH-GWP-2: Reduce Industrial High-GWP Emissions

Annual gross emission reduction compared to BAU in 2025:	12,600 $MTCO_2e$
In 2035:	37,600 $MTCO_2e$
In 2050:	50,200 $MTCO_2e$
Expected benefits	Improved safety and energy efficiency
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

Mitigation action HIGH-GWP-2 refers to reducing HFC emissions in the industrial sector through the implementation of a combination of regulatory and voluntary programs. The action assumes that if fully implemented, the transition to lower high-GWP gases in industrial end-uses will be achieved in 2040.

Methodology and assumptions: First, ICF selected a transition a target of 100% transition to lower-GWP alternatives for all industrial HFCs end-uses, and developed assumptions for feasible market penetration and reduction efficiency per end-use. Then, ICF modeled the forecasted emissions reduction for each industrial end-uses to achieve a 100% transition by 2040, based on market penetration and reduction efficiency percentages. The reduction efficiency factors take into account the difference in GWP from HFCs and alternatives, as described in EPA's 2012 Non-CO_2 GHG Emission Projections & Marginal Abatement Cost Analysis. It was assumed that all existing industrial systems that use high-GWP substances are retrofitted or replaced with alternatives and all new buildings will use natural HFC alternatives or HFC/HFO blends, resulting in no new HFC emissions for the refrigeration, foam, fire, and solvent sectors.

For this mitigation measure, Delaware would reduce high-GWP refrigerant emissions in the industrial sector by implementing Cool Switch and proposed Regulation 1151. Additionally, Delaware would implement programs to manage HFCs and other high-GWP materials throughout the product lifetime: installation, maintenance, disposal, reclamation. Management of HFCs and other high-GWP materials would include improved maintenance of current end-use applications to reduce leakage and phase outs of products using HFCs and other high-GWP materials.

Measure is impacted by: None.

Expected benefits: This measure will reduce emissions of high-GWP gases; it will also improve safety and energy efficiency.

NG-1: Methane Emission Reductions from Utility Gas Lines

Annual gross emission reduction compared to BAU in 2025:	143,000 $MTCO_2e$
In 2035:	238,600 $MTCO_2e$
In 2050:	238,600 $MTCO_2e$
Expected benefits	Air quality, employment
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

Mitigation action NG-1 includes implementing a Leak Detection and Repair (LDAR) program for utility gas lines. It would include a requirement for all utility gas lines to undergo quarterly LDAR inspections starting in 2021.

Methodology and assumptions: ICF calculated a 60% annual reduction in methane emissions from utility gas lines through LDAR compliance. The 60% target was based on EPA and ICF estimates and assumes that leaks are occurring at natural gas transmission and distribution facilities.

Measure is impacted by: None.

Expected benefits: In addition to reducing GHG emissions, this measure is expected to improve air quality through increased leak detection and reduction and provide employment opportunities.

TPORT-1: Low Carbon Fuel Standard (LCFS)

Annual gross emission reduction compared to BAU in 2025:	7,700 $MTCO_2e$
In 2035:	72,700 $MTCO_2e$
In 2050:	60,100 $MTCO_2e$
Expected benefits	Air quality, employment, diversified energy sources
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

Mitigation action TPORT-1 focuses on implementing a Low Carbon Fuel Standard (LCFS) to incentivize and increase the supply and use of low carbon fuels. The program would be based on the CARB program that uses a company-to-company credit and deficit trading system.

Methodology and assumptions: ICF estimated changes in fuel consumption and associated emissions from fuel switching to i) renewable diesel, ii) natural gas (i.e., compressed natural gas (CNG)), and iii) electricity from diesel. ICF focused on switches from diesel to the aforementioned alternatives for mainly heavy-duty vehicles (HDV) to avoid double counting, given that light-duty vehicles (LDV) fuel switching was accounted for in modeling for other actions. Annual changes in fuel consumption were estimated by linearly interpolating reductions in carbon intensity of the fuel mix in accordance with 10% and 20% carbon intensity reduction targets by 2030 and 2040, respectively. ICF then determined the amount of diesel consumption expected to be displaced annually by renewable diesel, natural gas, and electricity to achieve annual carbon intensity targets. Increased consumption of each replacement fuel for diesel was determined on an annual basis by dividing the difference between the diesel emission factor and the average replacement fuel emission factor by each fuel's energy economy ratio. The average replacement fuel emission factor for diesel is based on an energy pathway comprised of 25% CNG, 50% renewable diesel, and 25% electricity. This method is consistent with the calculations described in the CARB LCFS regulation.[6]

While this actions focuses on fuel switching from diesel, primarily in HDVs, fuel switching from gasoline to other fuels in LDVs is expected to support an LCFS as well. Because fuel switching to meet goals of the LCFS will be driven by a variety of policies and programs and not solely achieved through implementation of a LCFS, estimated emissions reductions from other fuel switching transportation actions (e.g., TPORT-4) contribute to the LCFS attainment and could be counted as emission reductions from LCFS instead of analyzed as separate actions.

Measure is impacted by: Expanded RPS (GRID-1); Fuel-Efficient Vehicles (TPORT-6); Vehicle Manufacturing Regulations (TPORT-3); Consumer EV Incentives (TPORT-4); Freight (TPORT-7)

Expected benefits: Implementing a LCFS can lead to improved air quality, which can provide health benefits and improved urban livability. It can also provide new employment opportunities, and benefit resilience by helping to diversify energy sources.

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[6]California Air Resources Board, LCFS Regulation. Available here: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/lcfs-regulation

TPORT-2: Light-Duty Vehicle Travel Demand Management and Land Use Strategies

TPORT-2 combines several travel demand and land use strategies. It includes strategies to reduce vehicle miles traveled (VMT) of private vehicles by implementing travel demand strategies such as shifting travel time, mode choice, route optimization, and increasing frequency of telecommuting. These are paired with land use and development policies that promote sustainable transportation modes (walking, biking, transit, carpool). As a result this action provides travelers the benefits of time and cost savings by shifting travel outside of peak times, reducing congestion by carpooling, or taking a different mode such as biking, walking, or transit.

Annual gross emission reduction compared to BAU in 2025:	66,800 $MTCO_2e$
In 2035:	190,000 $MTCO_2e$
In 2050:	302,800 $MTCO_2e$
Expected benefits	Air quality, employment, potential expansion of public infrastructure to support emergency services
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

Methodology and assumptions: ICF estimated changes in consumption of gasoline, diesel, and alternative on-road fuels (e.g., CNG, electricity) based on projected reductions in VMT that could result from implementing the above strategies. ICF then applied emission factors to estimate the amount of GHG emissions avoided resulting from reduced VMT. For these calculations, ICF assumed that all LDVs, regardless of the fuel used, have the same annual VMT. Annual LDV VMT is based on DelDOT projections for total state VMT and SIT historical data. Annual VMT reductions were assumed to increase linearly from the baseline year, 2020, to goal years, 2035 and 2050. ICF assumed a 10% decrease of LDV VMT from 2020 by 2035 and a 15% decrease of LDV VMT from 2020 by 2050. While some HDV VMT may be reduced through this action (e.g., more through more compact delivery routes), HDVs were not analyzed in this action.

Measure is impacted by: Expanded RPS (GRID-1)

Expected benefits: Implementation of this action is expected to provide benefits such as improved air quality, which can increase the health and livability of urban areas. This measure also provides an opportunity to benefit resilience by expanding public infrastructure that can reduce the impacts of climate change, such as green infrastructure that reduces urban heat island impacts or flood risks.

TPORT-3: Vehicle Manufacturer Regulations

Annual gross emission reduction compared to BAU in 2025:	5,200 $MTCO_2e$
In 2035:	37,500 $MTCO_2e$
In 2050:	102,400 $MTCO_2e$
Expected benefits	Air quality, employment
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

This action includes implementing regulations requiring vehicle manufacturers to make available specific quantities of ZEVs, including EVs, PHEVs, and hydrogen fuel cell vehicles. This would be implemented by requiring manufacturers to deliver a specific number of zero or low emissions vehicles to sell in Delaware, based on the total number of cars sold in the state by the manufacturer. Manufacturers with higher overall sales would be required to deliver a higher number of zero or low emission vehicles, and requirements would be in terms of percent credits. Each vehicle produced would receive credits based on its electric driving range. Credits not needed for compliance in any given year could be banked for future use, traded, or sold to other manufacturers. This type of regulation, commonly known as a ZEV program, has already been implemented by 12 other states (California, Colorado, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, Vermont and Washington) (Vermont Department of Environmental Conservation, 2020).

Methodology and assumptions: ICF estimated changes in fuel consumption from the displacement of conventional vehicles by new ZEVs. ICF then applied emission factors to estimate reduced emissions from displaced conventional fuels and additional electricity consumption. For these calculations, ICF made the following assumptions:

- All new ZEVs manufactured will displace the equivalent number of conventional vehicle sales.
- Allocation of displaced vehicle types is to equal BAU vehicle allocation.
- All LDV fuel types have the same annual VMT, adjusted annually to reflect VMT reductions over time.
- 20% of new vehicles must be ZEVs or Transitionary ZEVs (PHEVs and hydrogen vehicles) in 2025 and 70% in 2050.

Measure is impacted by: Expanded RPS (GRID-1), Transportation Demand Management (TPORT-2), Fuel-Efficient Vehicles (TPORT-6)

Expected benefits: In addition to reducing GHG emissions, vehicle manufacturer regulations and subsequent increases in ZEV sales are expected to lead to improved air quality in urban areas and near major roadways, by reducing tailpipe emissions. This can lead to improved urban livability and health outcomes. Additionally, implementing this measure is expected to create employment opportunities in ZEV manufacturing and sales.

TPORT-4: Consumer EV Adoption Incentives

Mitigation action TPORT-4: Consumer EV Adoption Incentives, includes expanding programs to advance EV adoption through vehicle incentives paired with increased infrastructure (charging stations, building codes, parking requirements), incentive programs (purchasing rebates), charging rate plans (off-peak, vehicle-to-grid), and legislation (interoperability, time-of-use rates, states agencies to charge for charging stations, EV-ready building/parking, multi-unit dwelling considerations).

Annual gross emission reduction compared to BAU in 2025:	169,500 $MTCO_2e$
In 2035:	441,200 $MTCO_2e$
In 2050:	1,072,800 $MTCO_2e$
Expected benefits	Air quality, employment
Net Present Value	$901.6 million
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	$60 / MTCO2e

Methodology and assumptions: ICF first estimated the change in fuel consumption from conventional vehicles displaced by increased adoption of EVs, and then estimated emission reductions based on fuel switching to electricity from conventional fuels. For these estimates, ICF made the following assumptions:

- The adoption rate of EVs increases linearly from the baseline year to goal years.
- New electric LDVs will displace current conventional vehicles using gasoline, diesel, and other on-road fuels (e.g., CNG).
- The allocation of displaced vehicles by fuel type is equal to BAU vehicle allocation by fuel type.
- EV adoption in the private passenger fleet as a result of the Vehicle Manufacturing Regulations measure (TPORT-3) contributes to the goals set in TPORT-4.
- Overall LDV EVs adoption rate of 20% by 2030 and 70% by 2050.

Measure is impacted by: Expanded RPS (GRID-1), Transportation Demand Management (TPORT-2), Fuel-Efficient Vehicle (TPORT-6), Vehicle Manufacturing Regulations (TPORT-3).

Expected benefits: This measure is expected to benefit air quality and urban livability. All-electric vehicles have zero tailpipe emissions, which helps to improve air quality in urban areas and near major roadways (U.S. Department of Energy 2020). This, in turn, can provide health benefits and improve quality of life. Additionally, implementation of this measure may provide new employment opportunities related to program administration and construction of EV infrastructure.

Economic methodology and assumptions: Costs reflect the difference between EVs and conventional internal combustion vehicles purchase prices and operation and maintenance (O&M) costs. EV purchase costs are currently higher (capital), but offer significant annual savings in fuel and maintenance costs. These costs are compared with the number of conventional vehicles replaced annually by EVs, to provide an annual estimate of total costs for the mitigation measure.

TPORT-5: State Fleet Electrification

Annual gross emission reduction compared to BAU in 2025:	1,300 $MTCO_2e$
In 2035:	3,400 $MTCO_2e$
In 2050:	9,300 $MTCO_2e$
Expected benefits	Air quality, employment
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

For mitigation action TPORT-5, the state of Delaware would lead by example by electrifying the state's vehicle fleet. State agencies will increase the number of EVs in light-duty fleets to at least 20% of the fleet by 2025, and to 100% by 2050.

Methodology and assumptions: ICF determined the fuel consumption from conventional vehicles displaced by increased adoption of EVs and calculated emission reductions based on fuel switching to electricity from conventional fuels. For these calculations, ICF made the following assumptions:

- All state fleet vehicles were assumed to be light-duty vehicles.
- All ZEVs purchased will displace the equivalent number of conventional vehicle sales.
- Fuel consumption by fuel type of the state fleet is identical to the distribution of fuel consumption by fuel type for private passenger vehicles.
- The allocation of displaced vehicles by fuel type is equal to BAU vehicle allocation by fuel type.
- State agencies will increase the number of ZEVs in light-duty fleets to at least 20% of the fleet by 2025, and to 100% by 2050.

Measure is impacted by: Expanded RPS (GRID-1)

Expected benefits: In addition to reducing GHG emissions, this measure is expected to contribute to improved air quality, which can lead to improved health outcomes.

TPORT-6: Fuel-Efficient Vehicles

Annual gross emission reduction compared to BAU in 2025:	14,300 $MTCO_2e$
In 2035:	28,200 $MTCO_2e$
In 2050:	58,300 $MTCO_2e$
Expected benefits	Air quality, energy supply resilience
Net Present Value	Not estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not estimated

Mitigation action TPORT-6: Fuel-Efficient Vehicles refers to expanded adoption of more fuel-efficient gasoline-powered private passenger vehicles. This would be achieved through the implementation of incentive programs and consumer outreach across Delaware.

Methodology and assumptions: ICF estimated fuel consumption reductions associated with improved LDV fuel economy in the state by estimating the difference between fuel consumption with BAU gasoline fuel economy and target gasoline fuel economies. For these estimations, ICF made the following assumptions:

- This measure only impacts gasoline-powered LDV.
- BAU gasoline fuel economy is equal to EIA's AEO Reference Case fuel economy estimates.
- Overall increase in average LDV on-road fleet fuel economy to 33.8 MPG by 2035 (42% improvement from 2019), based on EIA's AEO High Oil Price case.
- Overall increase in average LDV on-road fleet fuel economy to 38.5 MPG in 2050 (62% improvement from 2019), based on EIA's AEO High Oil Price case.

Measure is impacted by: Expanded RPS (GRID-1), Transportation Demand Management (TPORT-2)

Expected benefits: This measure is expected to reduce annual GHG emissions by reducing vehicle fuel consumption. Fuel-efficient vehicles also provide the benefit of improved air quality near roadways, which in turn can contribute to improved health and well-being in nearby communities. Finally, this measure can benefit energy supply resilience by increasing resource efficiency.

TPORT-7: Expand Freight Best Practices and Regulatory Actions

Annual gross emission reduction compared to BAU in 2025:	25,000 $MTCO_2e$
In 2035:	127,600 $MTCO_2e$
In 2050:	228,600 $MTCO_2e$
Expected benefits	Air quality, enhanced livelihoods, energy supply resilience
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

Mitigation action TPORT-7 is the expansion of freight best practices including mode switching, route optimization, and fuel efficiency.

Methodology and assumptions: *Route Optimization*: ICF estimated fuel consumption reductions resulting from route optimization by applying annual VMT reduction percentages to fuel consumption estimates. Annual fuel consumption reduction percentages were developed through linear interpolation, assuming a 5% reduction in route miles for HDVs with total market penetration. For each year, a 5% route mile reduction benefit was applied to the additional portion of market penetration for HDVs, assuming a baseline market penetration of 75% in 2020 and target market penetrations of 85% and 90% in 2035 and 2050, respectively. Total fuel consumption reductions were estimated by applying the mile reduction benefit to the additional portion of the market for each fuel type, accounting for the impact of efficiency and mode shift actions as well.

Mode Shift: ICF estimated fuel consumption reductions resulting from mode shift to rail by applying annual fuel consumption reduction percentages to fuel consumption estimates. Annual fuel consumption reduction percentages were developed through linear interpolation and 2030 and 2040 targets of 3% and 4.3% fuel consumption reductions, respectively. ICF took into account changes in fuel consumption from other HDV fuel efficiency actions to determine an adjusted BAU HDV fuel consumption and to avoid double counting reductions.

Fuel Efficiency: ICF estimated fuel consumption reductions associated with improved HDV fuel economy by estimating the difference between fuel consumption with BAU gasoline and diesel fuel economies and target fuel economies. Assumptions included a phase-in period for new fuel efficiency standards of five years, target market penetrations for improved fuel economy of 50% by 2035 and 95% by 2050, and a 20% improved fuel economy for each fuel.

For the above calculations, ICF made the following assumptions:

- The percentage of HDV fuel consumption in the BAU was based on the Oak Ridge National Lab' U.S. fuel mix percentages.
- All HDVs were assumed to have the same VMT.
- Biodiesel consumption was assumed to be negligible based on the amount of fuel consumption in the BAU and was not included in modeling for freight activities.
- BAU fuel economies for each fuel type were remained constant through the time series.

Measure is impacted by: Low Carbon Fuel Standard (TPORT-1)

Expected benefits: In addition to reducing GHG emissions, this action is expected to improve air quality, which in turn can provide health benefits and improve urban livability. It may also enhance resiliency, as resource efficiency is a benefit for energy supply resilience.

WASTE-1: Expanded Methane Capture

Annual gross emission reduction compared to BAU in 2025:	127,300 MTCO2e
In 2035:	299,100 MTCO2e
In 2050:	288,500 MTCO2e
Expected benefits	Air quality, employment, resilience benefits from on-site energy
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

WASTE-1, Expanded Methane Capture, is assumed to reduce methane emissions through improved controls and monitoring and expanded methane capture for RNG generation or flaring.

Methodology and assumptions: ICF used linear interpolation to determine methane emissions reduced over time from expanded methane capture from non-utility sources. ICF projected methane emissions from non-utility sources (e.g., agriculture, wastewater, and landfills) by scaling with population growth. ICF projected a 50% reduction in methane emissions from agriculture, wastewater, and landfill sources by 2030 due to expanded methane capture, and a 75% reduction by 2040. Targets are similar to the goals identified in other states, such as those for the state of California outlined in SB1383 for reducing methane emissions from waste sources.

Measure is impacted by: WASTE-2.

Expected benefits: Reducing methane emissions through this mitigation action can help improve air quality and provide employment opportunities. Additionally, it can help increase energy resilience by sourcing on-site energy.

WASTE-2: Waste Diversion and Reduction

Mitigation action WASTE-2: Waste Diversion and Reduction includes diverting waste from landfills through increased recycling and organic waste diversion (composting, land application, animal feed, etc.).

Annual gross emission reduction compared to BAU in 2025:	30,100 $MTCO_2e$
In 2035:	84,200 $MTCO_2e$
In 2050:	211,400 $MTCO_2e$
Expected benefits	Air quality, employment
Net Present Value	Not Estimated
Estimated cumulative cost / (benefit) per metric ton of CO_2e reduced	Not Estimated

Methodology and assumptions: ICF worked with DNREC to determine 2017 waste generation levels in Delaware, broken out by waste type where available. ICF characterized emissions (primarily methane) for these waste types (e.g., plastics, paper, organic waste) and used linear interpolation to determine tons of waste diverted over time, which was used to calculate avoided methane emissions. ICF projected waste disposal increases by scaling with population growth, projecting an increased landfill diversion of 30% from 2018 levels by 2035 and 70% by 2050 due to increased recycling and diverting organic material.

Measure is impacted by: WASTE-1

Expected benefits: In addition to reducing GHG emissions, this measure is expected to improve air quality and provide employment opportunities. It can also help conserve material resources and landfill space.

Summary and Next Steps

This technical analysis provides necessary information for the development of Delaware's Climate Action Plan. With the BAU Projections and Mitigation Actions Selection and Analysis now developed, DNREC can consider how to use these resources for planning and implementation. The BAU Projections provide the foundation of baseline emissions and can be readily updated to reflect for changes in emission sources and additional data. The Mitigation Actions Selection and Analysis maps out a pathway for reducing emissions and can be adjusted for assumptions, modeling approaches, and mitigation actions. Together these analyses can be updated in the future to adjust the guiding assumptions, modeling approaches, and selected mitigation measures to gauge progress towards goals and to direct additional policy and program actions. The two assessments together provide a valuable model for informing Delaware's ongoing and future climate action planning efforts.

Key Takeaways

The BAU analysis projects that Delaware will reduce emissions by 25.4% in 2025 and by 19.6% in 2050, relative to 2005 levels, without additional GHG mitigation actions. This means Delaware will fall short of the USCA goal of 26-28% emission reductions by 2025 if no additional action is taken. However, Delaware can meet the USCA goal, and has potential for greater reductions in the mid and long term, if additional action is taken.

Net GHG emissions in Delaware will decline from 2005 levels by 31.1 % in 2025 and by 59.7% in 2050 if all 20 GHG mitigation actions were to be implemented. By implementing all of the selected mitigation actions, Delaware is projected to decrease emissions by an additional 5.7 % and 40.1% more than in the BAU scenario by 2025 and 2050, respectively. These results represent a subset of potential actions that were modeled by the project team and should not be interpreted as the only set of actions that can be taken to reduce GHG emissions; nor should the summary information presented be interpreted as the full potential costs and benefits of GHG reduction actions for the State.

Key takeaways from the mitigation analysis include:

- Decarbonizing the electricity grid has the greatest potential for reducing GHG emissions in the medium and long terms and drives emission reductions for many actions. Decarbonizing other energy sources may also play a larger, longer-term role in Delaware.
- Electrification of transportation and buildings can also lead to notable GHG reductions over time, but are dependent on decarbonizing the grid for full effectiveness.
- Energy efficiency is an important strategy that can be implemented in the short-term and is a relatively lower cost strategy for reducing GHGs.

Next Steps

Moving towards implementation will require DNREC, other state agencies, and key stakeholders to collaborate in considering:

- **Mitigation action timelines** – Some mitigation actions can provide immediate returns economically and may be easier to implement in the short-term without significant actions by the state, such as energy efficiency actions.

- **Mechanisms for implementation** – Greater needs for state intervention, such as legislation, or policy actions can delay implementation of mitigation actions.
- **Costs to the state or consumers** – Mitigation actions that require significant capital investments by either the state or consumers may require supplemental funding sources or policies to support implementation. Implementation should aim to manage costs while maximizing benefits.
- **Co-Benefits** – GHG reductions and costs are not the only criteria to consider—other benefits, such as climate resilience, health, job creation and equity factors are critical decision criteria.
- **Equity in planning** – Mitigation actions should be closely examined to understand how marginalized or vulnerable populations may be affected, and if mitigation actions that create significant benefits for these communities can be prioritized.

Building on this assessment and moving toward implementation will ensure that DNREC and Delaware can successfully achieve short- and long-term emission reductions, while also providing valuable benefits to stakeholders.

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